### 3.4.2 2-yr 24-hr Precipitation Charts

To derive a 2-yr 24-hr precipitation chart, a frequency analysis was made of the annual maximum 24-hr rains for almost 600 stations in and near the Tennessee Basin with 15 yr or more of record as of 1980. Figure 58 shows that a 15-yr record tends to yield results not greatly different from those from a 60-yr record. An analysis of the 2-yr 24-hr values in the eastern portion of the basin is shown in figure 59.

The 2-yr 24-hr analysis shown here was expanded from the analysis drawn in HMR No. 45 (fig. 3.18) to include all of the stippled region of HMR No. 51 (roughly equivalent to the eastern portion of the region). This was done by including in the analysis additional station data from Technical Paper No. 29 (1957) and other data currently available since the publication of Technical Paper No. 29. While most of the 2-hr 24-hr data is derived from the same time period, the minimum period of record for use in the analysis was 15 yr.

The analysis shown in figure 59 will be used in computing the areal distribution of the PMP and TVA precipitation for basins in the eastern portion of the watershed (sect. 5.3.3.2).

### 3.4.3 Extreme Monthly Rains in Subbasins

Monthly precipitation averages over subbasins, published in "Precipitation in the Tennessee Valley" were also used for evaluating orographic effects. Subbasins with strongest orographic effects, as indicated by a total orographic adjustment factor (see table 21 in chapter 6) will tend to show highest monthly averages.

Several of the storms producing significant rainfall amounts in the Tennessee River watershed and discussed in the text occurred between 1955 and 1965 (see for example sections 2.1.2 and 3.2.3). Therefore, it was arbitrarily decided to use the 11-yr period 1955-1965 as a means of showing variation of highest monthly precipitation over subbasins in the eastern portion of the watershed. Figure 60 depicts for the eastern portion of the Tennessee River watershed the average of the three highest monthly precipitation values during the 11-yr period; the months contributing these values are listed in table 10*. In particular, the October 1964 storm is emphasized by underlining. This is because of the significant heavy rains which penetrated portions of the watershed during this month (see sect. 3.2.3 for more discussion of the storms which produced large amounts of precipitation). The highest individual monthly values are shown in figure 62 with the dominance of certain stormy months in contributing these values over certain areas indicated by various hatchings.

### 3.4.4 Small-Basin PMP

Another indicator of orographic influence, which to a certain extent makes use of other indicators, is the 6-hr 1-mi$^2$ PMP (figs. 22 and 23) vs. the "smooth" value that would be calculated at the position in the absence of terrain

*TVA zones indicated in the left of table 10 are shown in figure 61.

Table 10.--Dates of highest monthly precipitation over mountainous eastern zones

(1955-1965)

| TVA* Zone | Drainage | Highest | 2nd Highest | 3rd Highest |
|---|---|---|---|---|
| 40 | Hiwassee | Sept. 1957 | July 1963 | July 1958 |
| 41 | Ocoee | July 1958 | Sept. 1957 | Oct. 1964 |
| 46 | Toccoa | July 1958 | Oct. 1964 | June 1961 |
| 48 | Hiwassee | July 1958 | Aug. 1964 | Aug. 1960 |
| 49 | Hiwassee | July 1958 | Aug. 1960 | July 1963 |
| 52 | Nottely | Oct. 1964 | July 1958 | June 1963 |
| 53A | Hiwassee | July 1958 | Oct. 1964 | Aug. 1960 |
| 54A | Hiwassee | Oct. 1964 | Oct. 1959 | July 1958 |
| 55 | Valley | July 1958 | July 1963 | June 1957 |
| 62 | Clinch | Sept. 1957 | June 1960 | July 1965 |
| 63 | Powell | Sept. 1957 | July 1956 | June 1957 |
| 65 | Clinch | Sept. 1957 | July 1956 | June 1958 |
| 67 | Tennessee | Sept. 1957 | July 1963 | July 1958 |
| 69 | Little Tennessee | July 1963 | June 1957 | July 1958 |
| 70 | Little Tennessee | Aug. 1964 | July 1963 | June 1957 |
| 71 | Cheoah | July 1963 | June 1957 | July 1958 |
| 72A | Little Tennessee | Aug. 1964 | July 1963 | July 1958 |
| 73 | Tuckasegee | July 1958 | Aug. 1964 | Aug. 1960 |
| 74 | Tuckasegee | Oct. 1964 | Oct. 1959 | Aug. 1964 |
| 75 | Little Tennessee | Oct. 1964 | July 1958 | Oct. 1959 |
| 78 | Nantahala | July 1958 | Oct. 1964 | Oct. 1959 |
| 84 | French Broad | Aug. 1984 | July 1956 | June 1957 |
| 87 | Holston | July 1958 | July 1956 | Oct. 1959 |
| 88 | Holston | Sept. 1957 | July 1958 | June 1957 |
| 89 | Holston | June 1957 | July 1956 | July 1958 |
| 92 | Holston | July 1958 | July 1956 | Aug. 1957 |
| 93 | Watauga | July 1956 | Aug. 1961 | June 1957 |
| 99 | French Broad | Aug. 1964 | July 1958 | June 1957 |
| 101 | Pigeon | Aug. 1964 | Oct. 1964 | July 1958 |
| 105 | Pigeon | Sept. 1959 | Sept. 1957 | Oct. 1964 |
| 106 | French Broad | Aug. 1964 | July 1956 | June 1957 |
| 110 | French Broad | Aug. 1961 | Oct. 1964 | Sept. 1959 |
| 114 | French Broad | Aug. 1961 | Oct. 1964 | Sept. 1959 |
| 117 | French Broad | Aug. 1961 | Oct. 1964 | June 1957 |
| 120 | Nolichucky | July 1956 | Aug. 1964 | July 1965 |
| 121 | Nolichucky | Aug. 1961 | June 1957 | Sept. 1957 |

*TVA zones shown in figure 61.

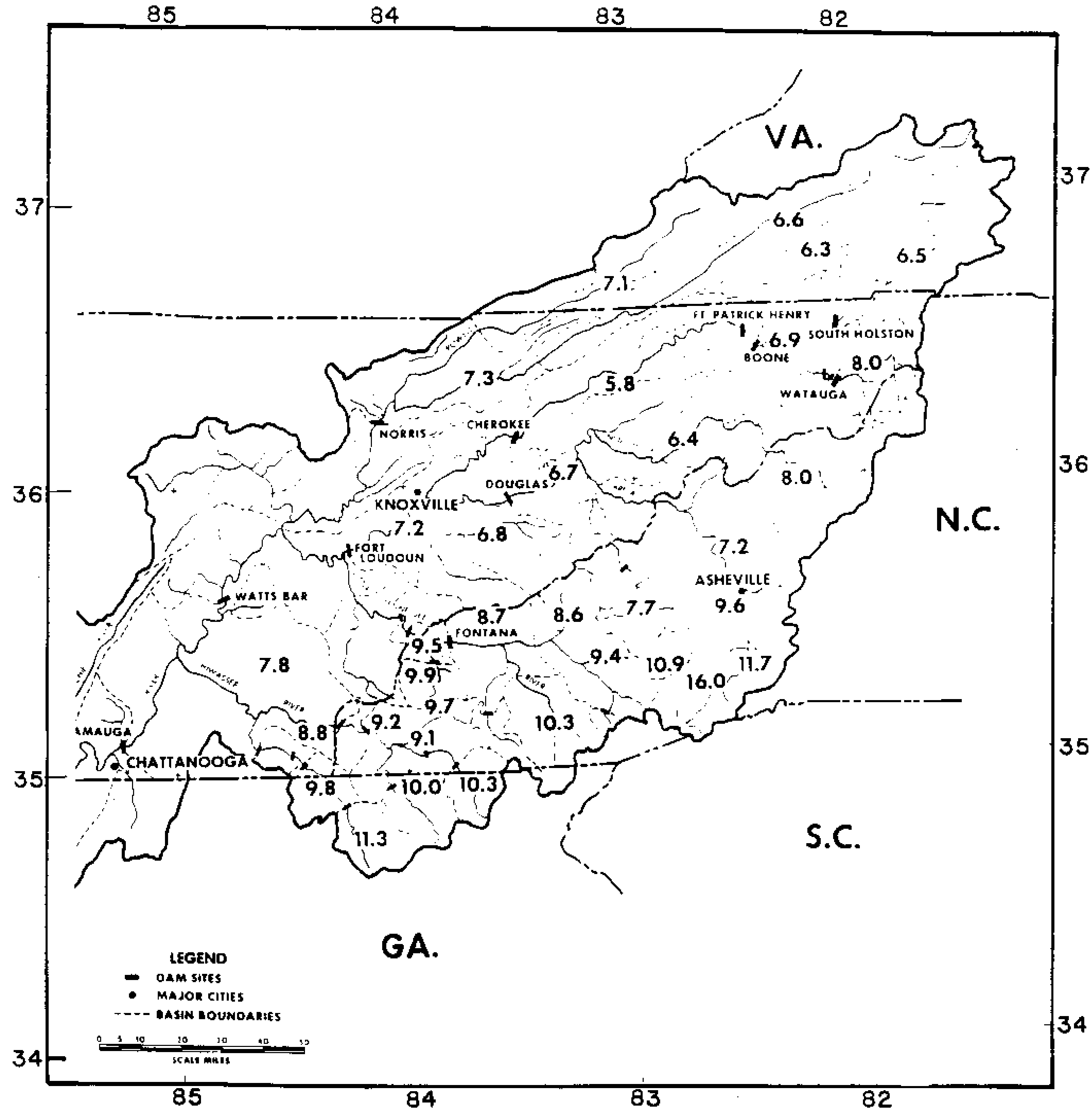


**Figure 60.--Average of highest three months (table 10) of subbasin precipitation (in.) applicable to the overall critical wind direction.**

features. This is used as a specific index relation in the generalized procedure to be described in section 5.4.3.2.

### 3.4.5 Optimum Wind Direction

Over a small basin--a few ten's of square miles -- it is presumed that the wind direction most favorable for unobstructed inflow of moist air and accentuation of lift by ground slope prevails during the PMP or TVA storm. In larger basins, the optimum direction for precipitation may differ from one portion of the basin to

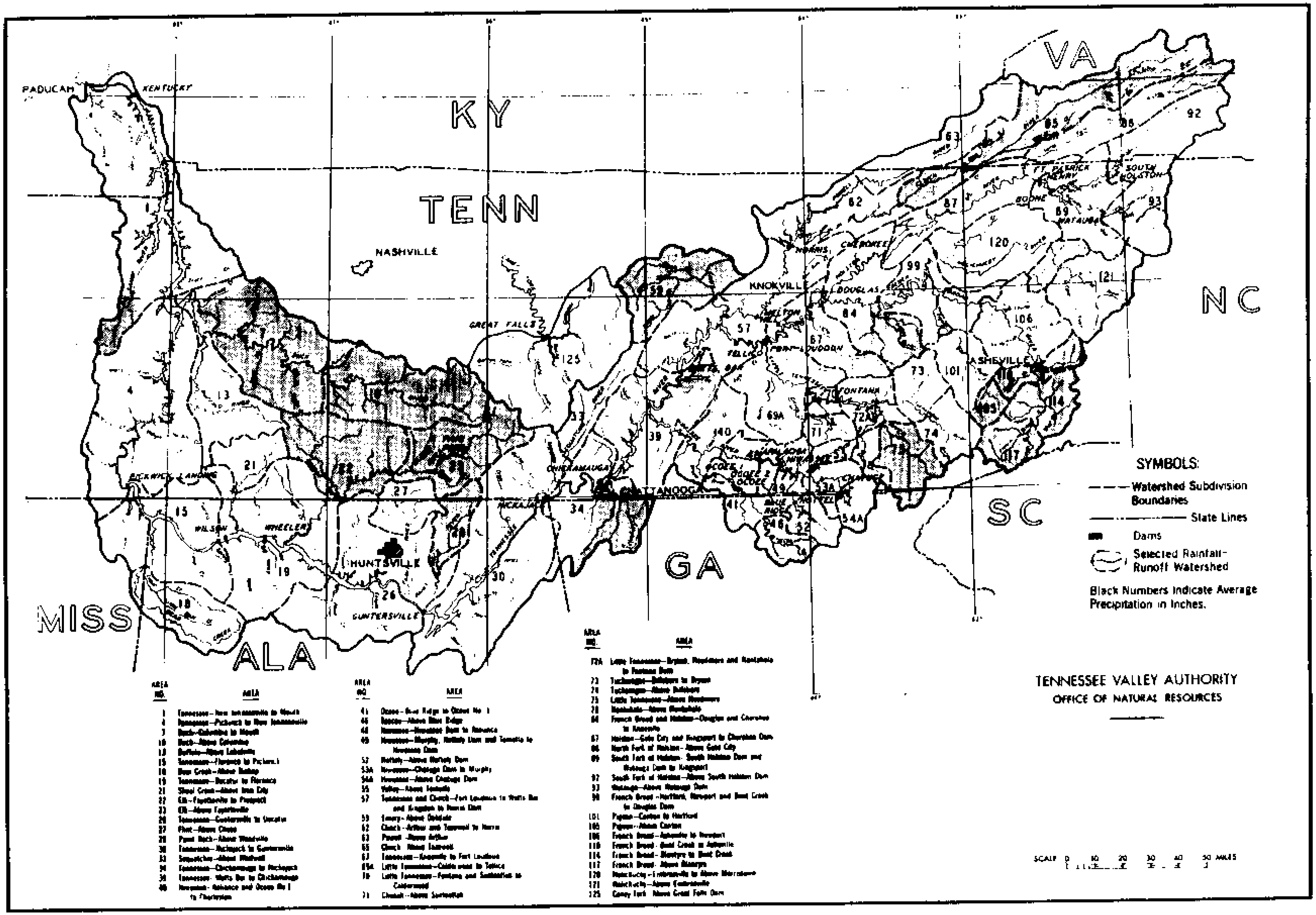


**Figure 61.--TVA zones.**

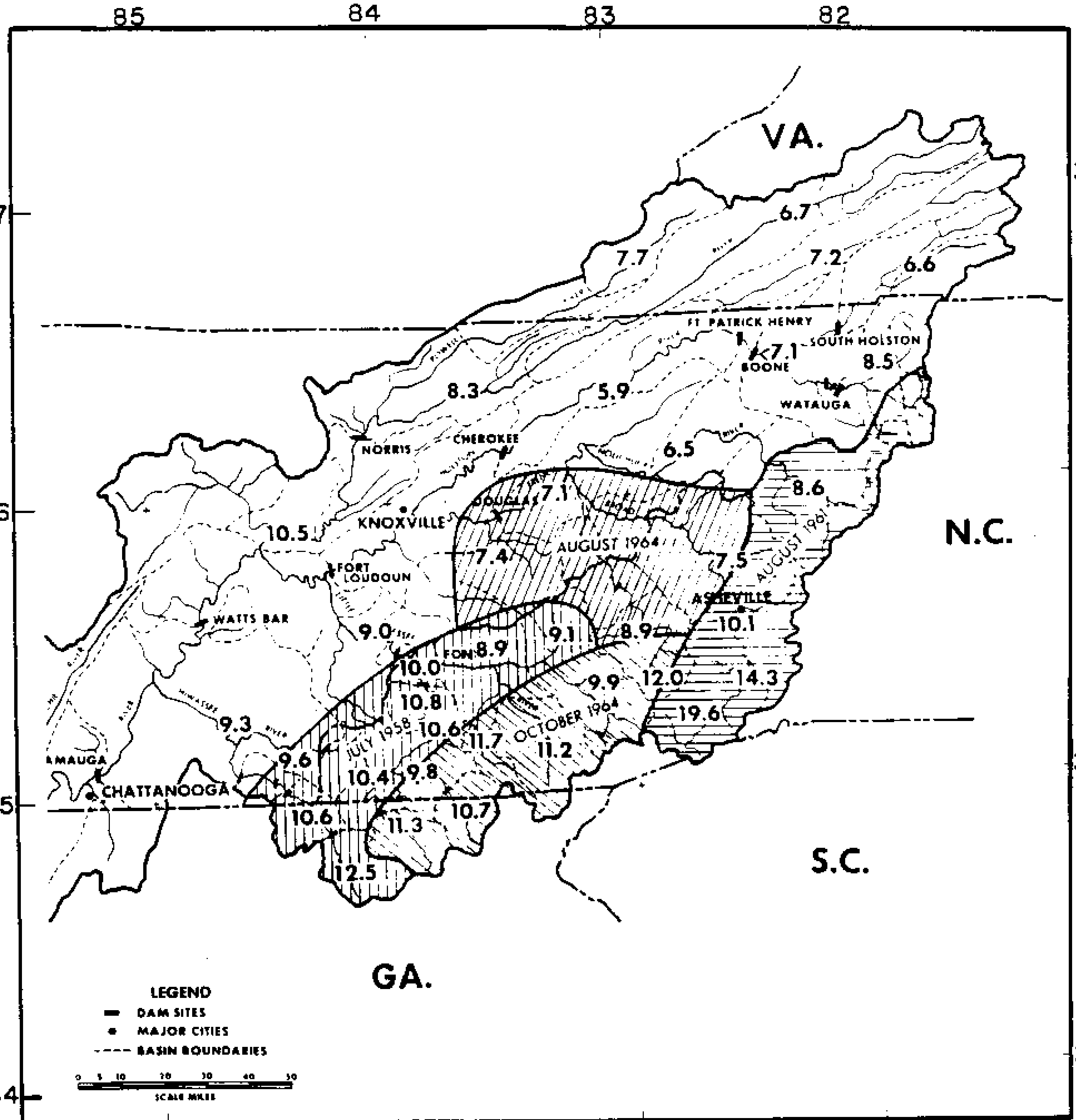


**Figure 62.—Highest monthly (table 10) subbasin amount (in.). Hatched areas show limits of control by specific storms.**

another because of varying orientation of principal slopes. The wind direction most critical for the basin as a whole is defined as the direction that is optimum over the largest fraction of the basin. A procedure is applied whereby the terrain intensification factor is related to the fraction of the basin for the optimum wind direction. Figure 63 shows the optimum moisture inflow direction for the mountainous eastern Tennessee River basins as either of southeast, south, southwest, or west. The figure was developed with the use of observed wind and precipitation data in each subbasin. Storms of significant magnitude, such as the September 28–October 4, 1964 storm described in section 3.2.3, were used in developing figure 63. The directions shown for each subbasin in figure 63 were derived by determining which wind direction, on the average, produced significant amounts of precipitation in the subbasin. In other

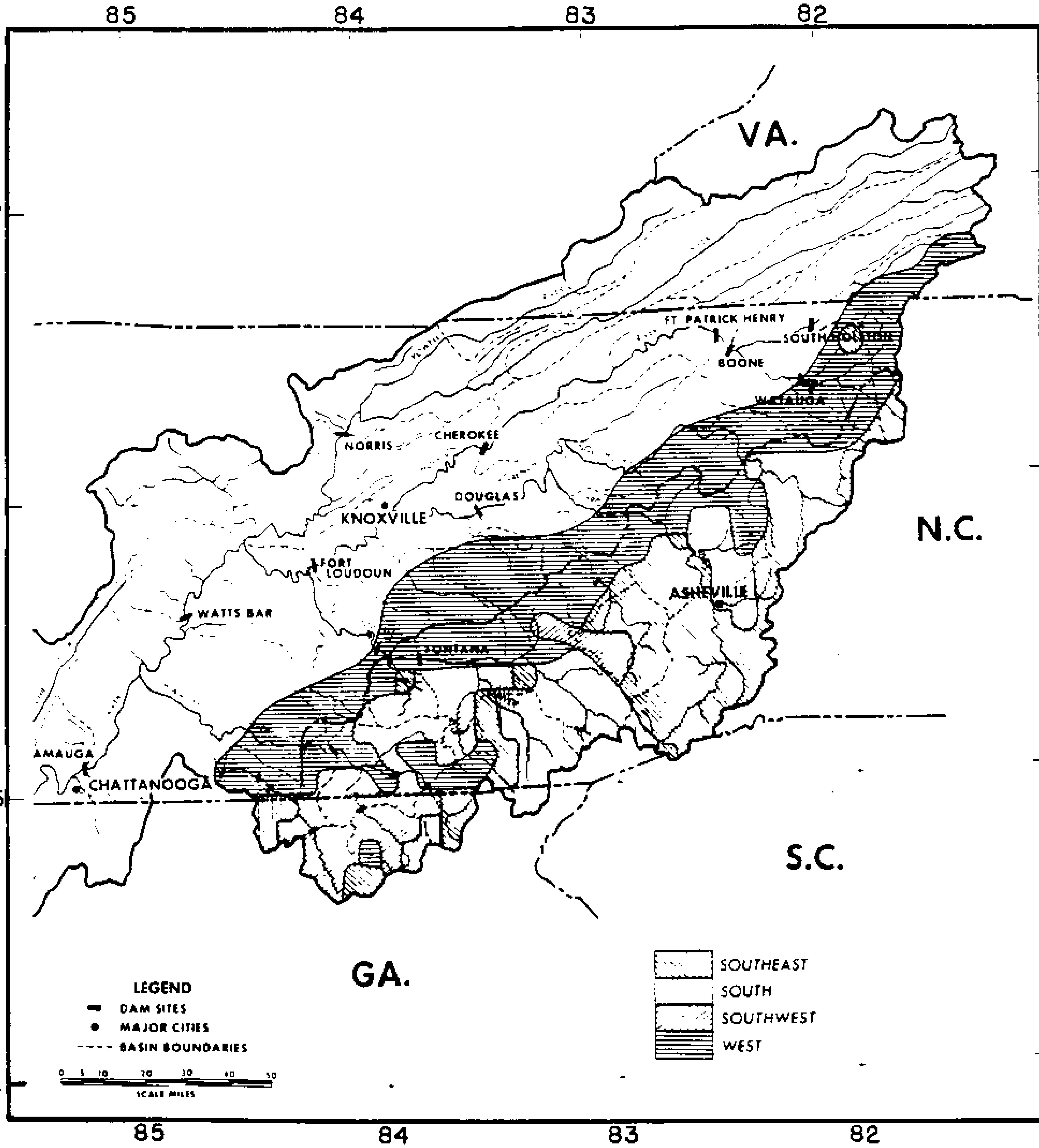


**Figure 63.--Areas controlled by specific "optimum" wind directions.**

words, the wind direction conducive to supplying an "optimum" amount of moisture to the subbasin was selected in figure 63. In applications, it is necessary to determine the largest percentage of the total basin covered by one of these directions. Using this percentage, the optimum wind adjustment factor is then determined from figure 64. Figure 64 was the result of empirical adjustments needed in making specific basin estimates in the region. To derive the relationship, specific adjustments were determined for subbasins 1 through 15 listed in table 22 and shown in figure 100. The specific estimates were obtained by looking at observed values of heavy precipitation in each subbasin. A subjective analysis was made to determine the amount of orographic influence on

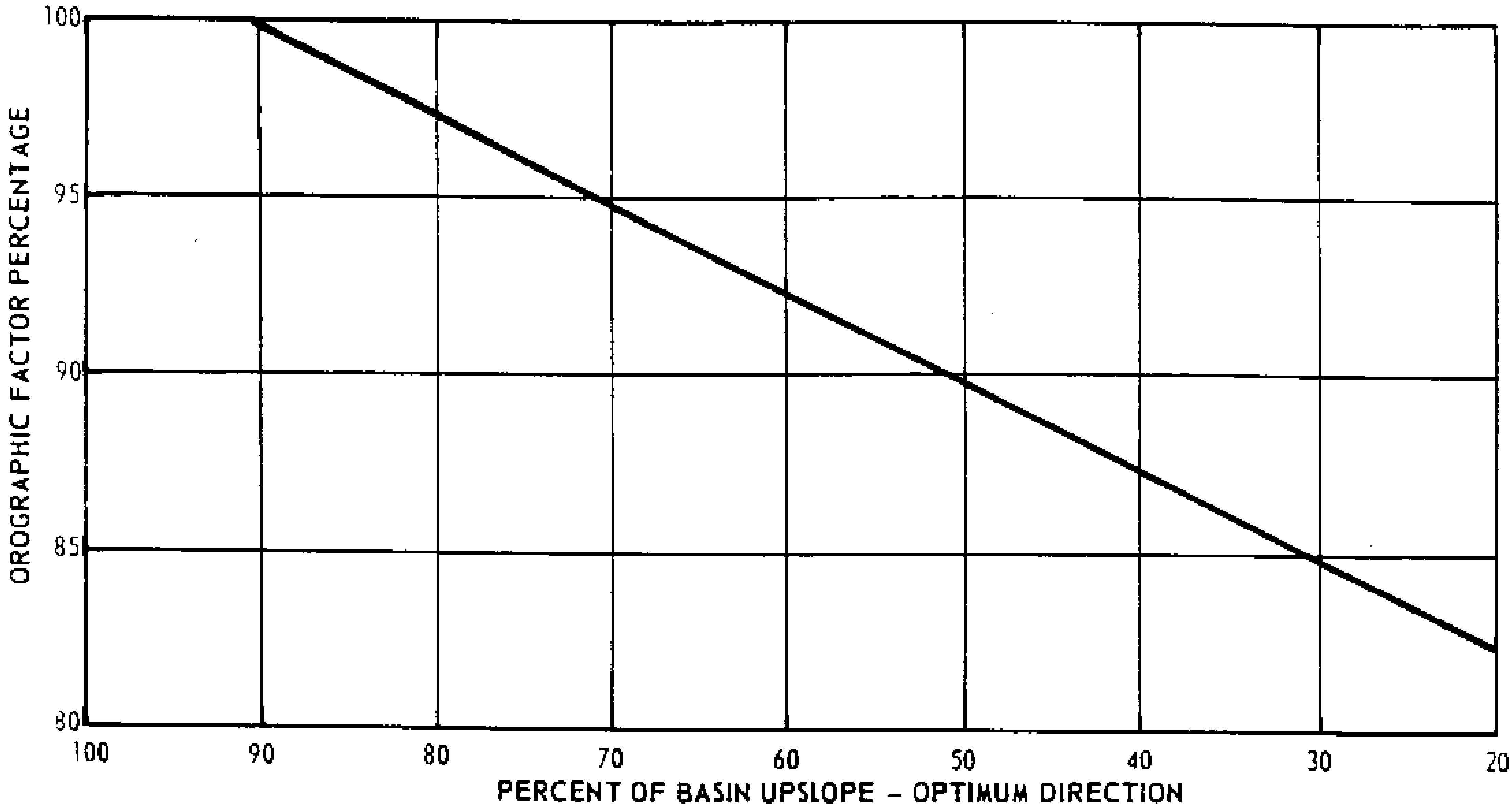


**Figure 64.--Orographic wind adjustment chart.**

total rainfall in each case. In addition, the percentage of the subbasin with a common wind direction was determined. These values were plotted on a graph similar to figure 64 and a line of "best fit" was established which is the line shown in figure 64.

## 3.5 Terrain Adjustment Methods

### 3.5.1 Introduction

As described in section 3.3.1 and 3.3.3, nonorographic PMP for area sizes between 100 and 3,000 mi$^2$ are obtained by multiplying a Knoxville, TN PMP value (fig. 52) for the selected area size by a geographic variation factor (figs. 54 and 55). In order to determine the total PMP, a terrain stimulation factor (TSF) must also be applied. This factor is related to the geographic location of the basin and its area size. In the mountainous east, the TSF must be modified by a sheltering effect and by an optimum wind adjustment before combining with the broadscale orographic factor (BOF) to develop a total adjustment factor (TAF). These adjustments are described in section 3.5.2 for the entire Tennessee River Valley, except the mountainous east. The adjustments for the mountainous east are described in section 3.5.3.

### 3.5.2 Terrain Stimulation Factor (TSF) for the Tennessee River Valley

The nonorographic PMP developed in section 3.3.1 does not consider the effect of terrain stimulation on convective cells and/or thunderstorms in general storms. In the small-basin procedure (chap. 2) this terrain stimulation was accounted for by development of separate depth-duration curves for "smooth",

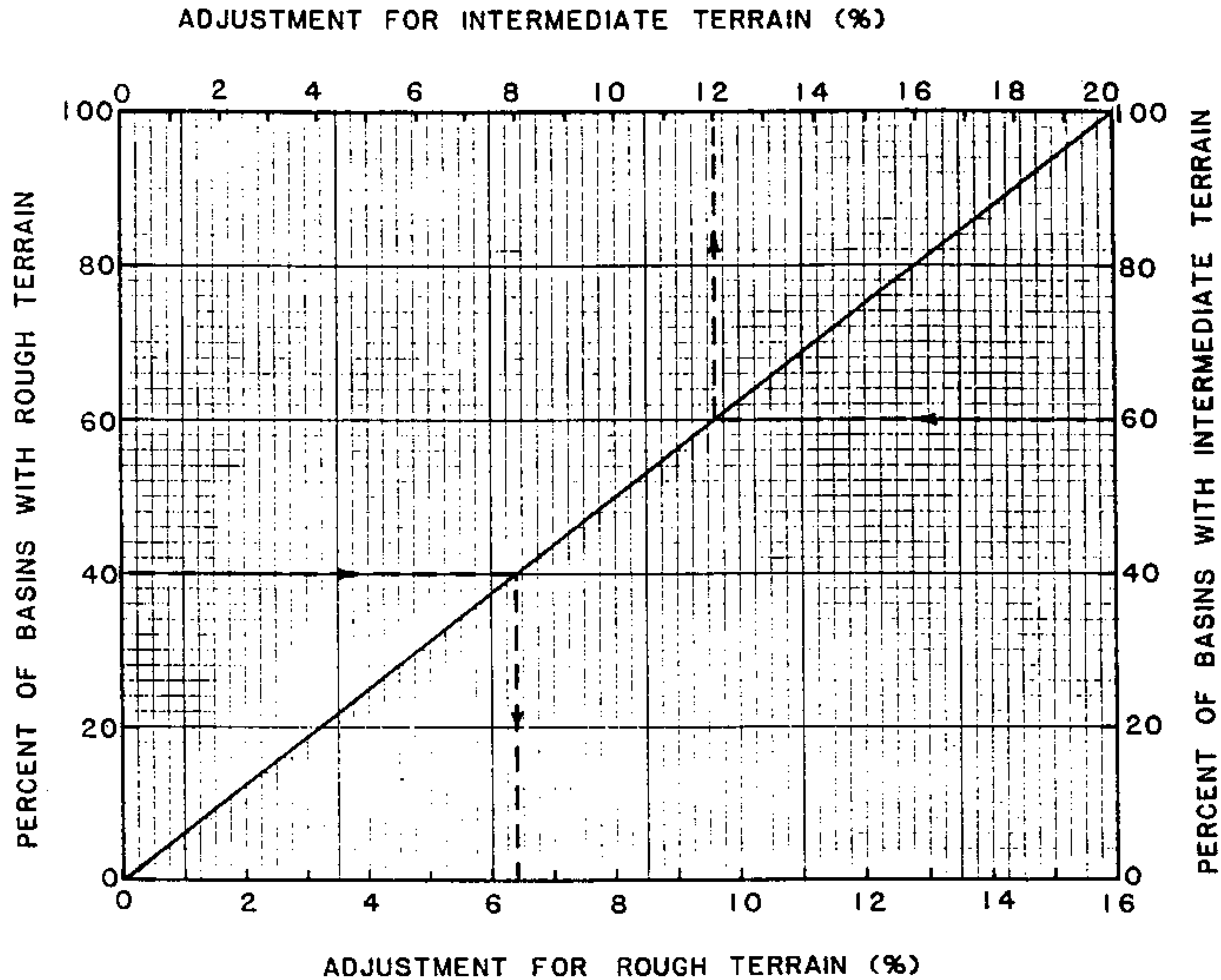


**Figure 65.--Adjustments to large-area basins for terrain roughness valid for $100\text{-mi}^2$ areas.**

"intermediate", and "rough" terrain. The adjustment in the large-basin procedure for this terrain stimulation effect uses these same criteria.

The adjustments to be applied to large-basin estimates for terrain stimulation effects are given in figures 65 and 66. These figures were developed empirically in the Addendum to HMR No. 45 to account for differences obtained at the interface ($100\ mi^2$) when using either the small-basin or large-basin procedure. Modifications were made to figure 66 because of the changes made to figure 16 in this report.

The logic of applying these adjustments is that a roughness factor that causes terrain stimulation (from "fixing" and "triggering" of thunderstorm activity over small basins) is applicable in a modified form (decreasing effect) for basins

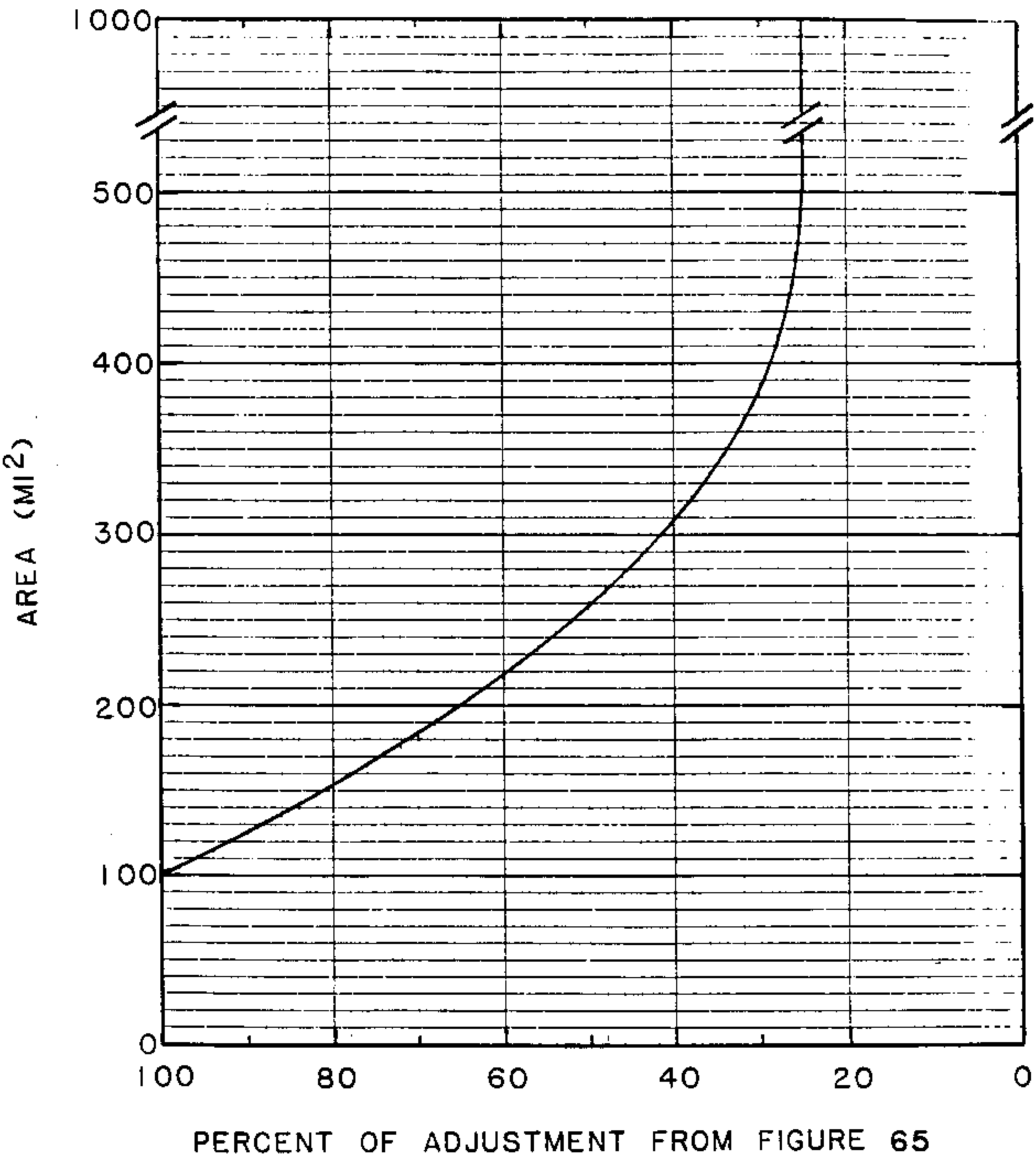


**Figure 66.--Variation of terrain roughness adjustment (fig. 65) with basin size.**

larger than 100 $mi^2$. However, it is not realistic to assume that all-rough areas will be effective in promoting thunderstorm fixing and triggering. The importance of thunderstorm rainfall within the total precipitation volume decreases with increasing area size. The adopted decrease in the stimulation effects associated with thunderstorm rainfall with increasing area size, shown in figure 66, is applied to the values determined from figure 65. One reads the areal adjustment from figure 66 that is applied to the terrain adjustment determined from figure 65 for the basin under consideration. Adjustments for basins greater than 500 $mi^2$ remain constant at 25 percent of the adjustment determined in figure 65 for 100 $mi^2$. As an example, consider an all rough

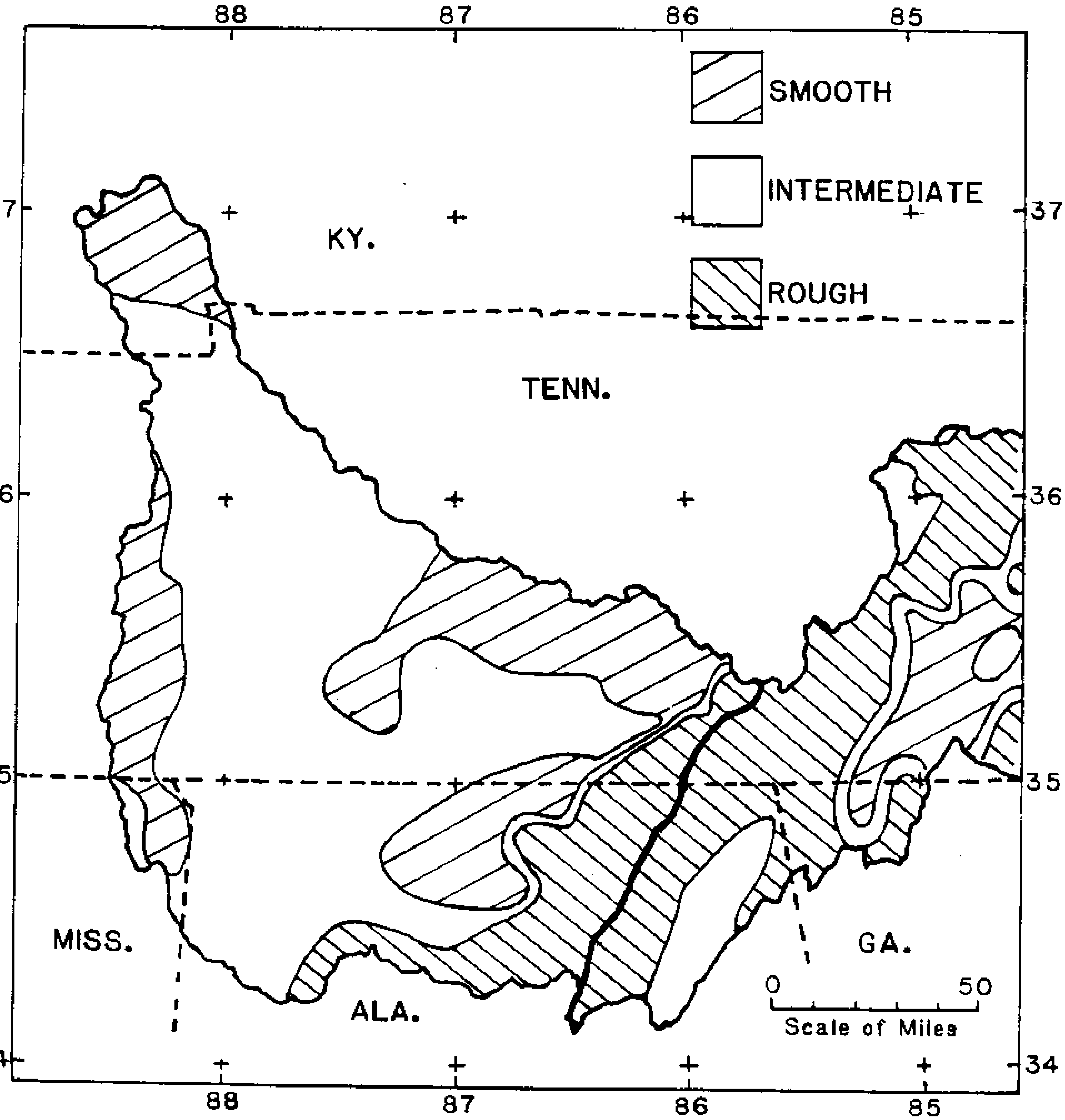


**Figure 67.—Distribution of terrain, western Tennessee River watershed. (Note the overlap of the eastern region shown on fig. 68.)**

1,000-$mi^2$ basin. The combined adjustment amounts to an increase of 4 percent (i.e., 16 percent from fig. 65 times the 25 percent from fig. 66).

To use the adjustments in figures 65 and 66 for all basins of 100 $mi^2$ or more, it is first necessary to determine those parts of the basin that are covered by rough and intermediate terrain (smooth is not considered here). These classifications are shown on figures 67 and 68. To apply the adjustment to a drainage entirely in one region, determine the percent of the basin in each of the two terrain categories (rough and intermediate) and compute the adjustments based on these percents (fig. 65) and the modification of the total adjustment for area size (fig. 66). As an example, suppose a 200-$mi^2$ basin in the eastern half of the Tennessee River Watershed (non-mountainous east region) has 20

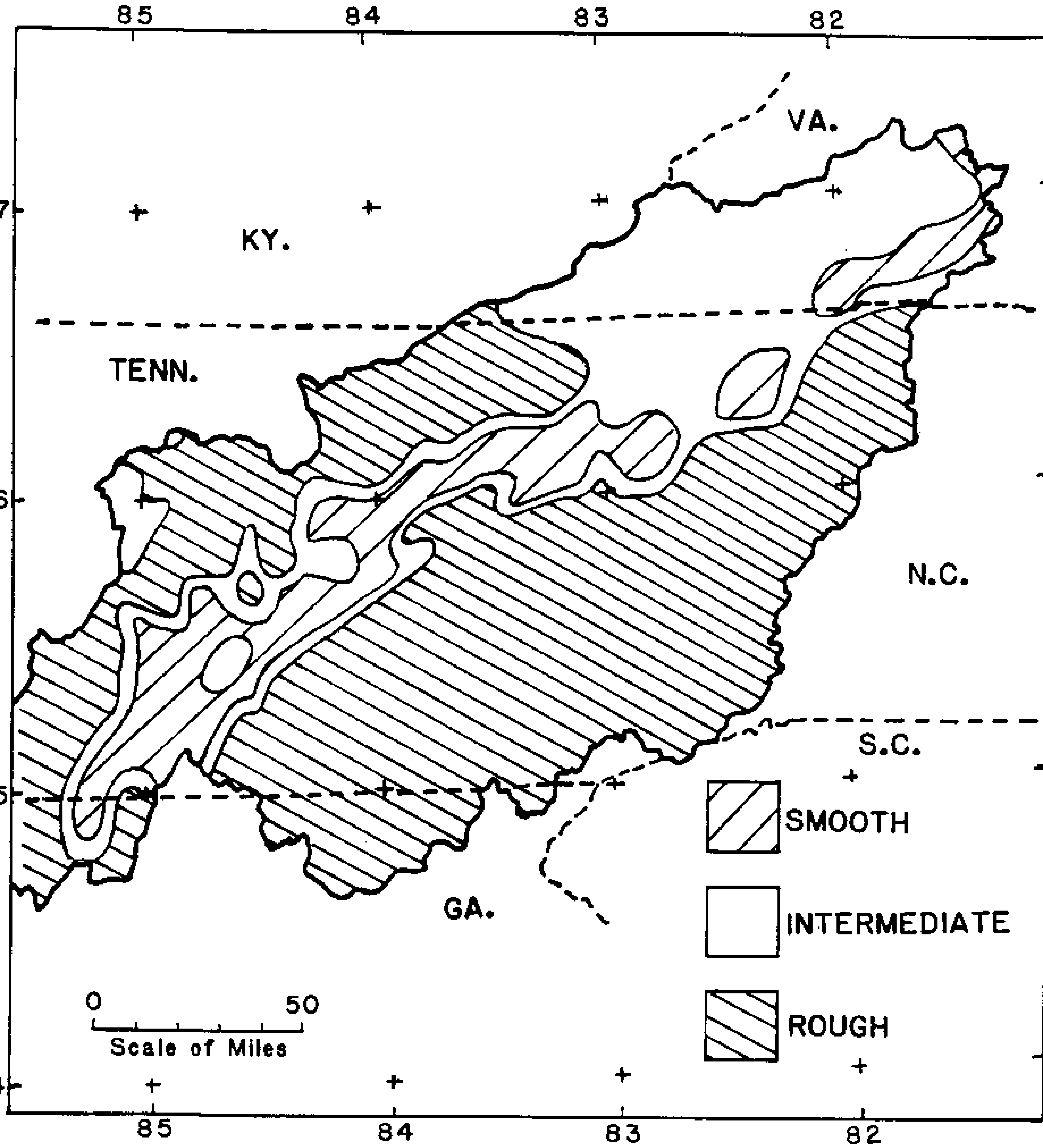


**Figure 68.--Distribution of terrain, eastern Tennessee River watershed.**

percent of its area classified rough and 50 percent intermediate (the 30 percent smooth terrain has no adjustment). A combined adjustment is then obtained from figure 65, considering the percent of the basin in rough and intermediate terrain. In our example, the combined adjustment amounts to 13 percent (3 percent (fig. 65) for the 20 percent rough portion of the basin, plus an additional 10 percent (fig. 65) for the 50 percent intermediate portion of the basin. Therefore, the nonorographic basin PMP and TVA precipitation values are increased by a total of 13 percent for the "roughness" of the basin topography. This 13 percent would apply unadjusted if the basin were 100 $mi^2$. The reduction to this stimulation increase for basin size is obtained from figure 66. The 13 percent increase from figure 65 is multiplied by the 64 percent from figure 66 for the 200 $mi^2$ area of the basin. In our example, this would give a total increase of 8.3 percent for this example. Thus, the TSF for this basin would be 1.083.

### 3.5.3 Total Adjustment Factor (TAF) for the Mountainous East

In the mountainous east, in addition to the terrain stimulation effect discussed in section 3.5.2, it is necessary to consider the broadscale orographic factors (BOF). The combination of the TSF and BOF in this region is the total adjustment factor (TAF). However, it first must be recognized that the TSF in this region needs to be further modified from that given in section 3.5.2. These modifications are the result of sheltering effects and consideration for the optimum wind direction.

The need for these additional factors in determining the TSF can be better understood by reference to the small-basin 6-hr 1-mi$^2$ PMP map (fig. 23). In the mountainous east region of figure 23, note that although the entire region is classified as "rough," there are several areas where the 6-hr 1-mi$^2$ PMP is less than 37.4 in. (the threshold for rough classification). This is the result of sheltering effects of the terrain on thunderstorms. Therefore, before determining the TSF, it is necessary to first remove the effects of all-rough terrain from figure 23 in the mountainous east.

The next step is to determine the TSF as done in section 3.5.2, but modified by consideration of sheltering and optimum wind direction as discussed in section 3.4.5. Then, determine the BOF by evaluating the percent of the basin comprised of primary upslopes, secondary upslopes and sheltered areas discussed in section 3.4.1. Finally, the modified TSF and BOF are added to obtain the TAF.

This rather complex adjustment determination can best be clarified by an example. Suppose a 300-mi$^2$ basin centered at 35.85°N 83°W, in the mountainous east, has a 6-hr 1-mi$^2$ basin average PMP of 40.1 in (from fig. 23). Since the basins located in the mountainous east are all 100 percent rough, there is a small-basin terrain-roughness from figure 65 of 16 percent. Dividing the 40.1 in. by the factor 1.16 gives 34.6, which removes all of the thunderstorm-induced terrain effect at a basin size of 100 mi$^2$, so that the appropriate terrain stimulation adjustment for the size of the basin can now be determined as in section 3.5.2. Figure 66 is used to obtain the adjustment for the size of the basin, 300 mi$^2$. The adjustment is 42 percent of the total 16 percent (for the all-rough basin), or 6.72 percent. Multiplying the 34.6 by 1.0672 gives 36.9 in. This is the nonorographic TSF-adjusted PMP.

The next step is to evaluate the modification caused by the sheltering effect on the nonorographic 6-hr 1-mi$^2$ PMP (fig. 16). The smooth basin PMP for 6-hr 1-mi$^2$ of 34.4 in. (the smooth 6-hr 1-mi$^2$ value at the southern edge of the Tennessee River watershed, or the 0-percent correction line of figure 69) is obtained from figure 16. Determine the sheltering factor from figure 69 applicable to the basin.

For the basin in this example, figure 69 gives a sheltering effect of 6 percent which must be subtracted from 100 to obtain the sheltering factor, 94 percent, that is multiplied by 34.4 in.. This product is 32.3 in. By dividing the TSF-adjusted PMP of 36.9 in. by the smooth PMP adjusted for sheltering of 32.3 in., or 1.14, one obtains the percentage orographic increase applicable to the basin. Thus, the TSF gives a 14 percent increase in the 6-hr 1-mi$^2$ PMP related to fixing and triggering of thunderstorm activity.

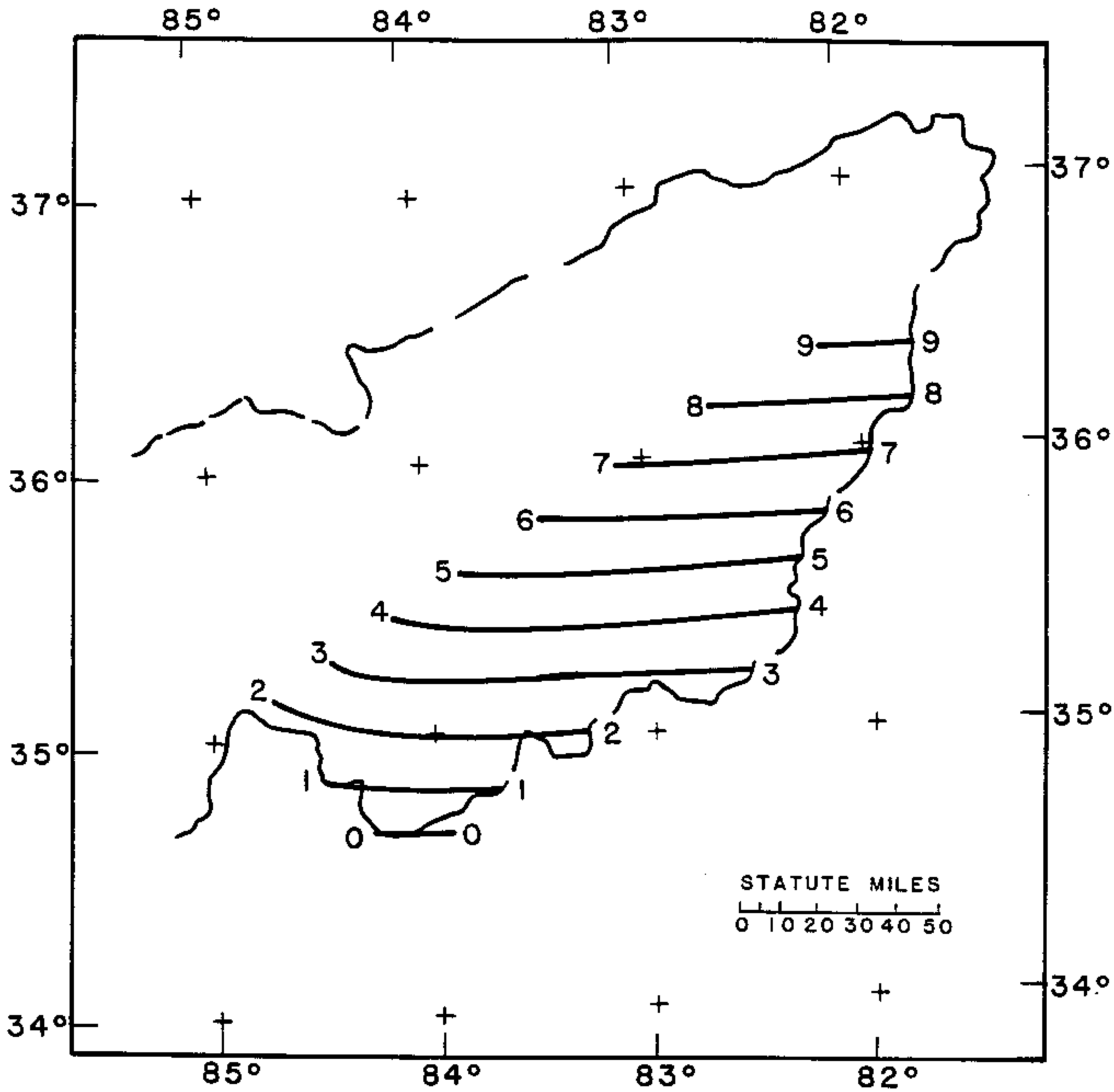


**Figure 69.--Generalized adjustment for terrain sheltering in the eastern half of the Tennessee River drainage basin (percent reduction in PMP and TVA precipitation).**

To adjust the TSF for optimum wind direction, enter figure 63 and determine the direction covering the greatest portion of the basin. For this example, 85 percent of the basin is covered by westerly winds. Enter figure 64 at 85 percent on the abscissa and read the adjustment factor of 98 percent. Multiply the TSF of 1.14 by 0.98 to get the final modified TSF of 1.12.

To determine the BOF, consider the percent of the basin covered by primary upslopes, secondary upslopes and sheltered areas in figure 14. If, in this example, these percentages are, respectively, 20, 40 and 40; then, using the factors given in section 3.4.1 of 0.55, 0.10, and 0.05, the BOF is (.20)(.55) + (.40)(.10) + (.40)(.05) = .11 + .04 + .02 = .17. The BOF is rounded to the nearest 5 percent, or 0.15.

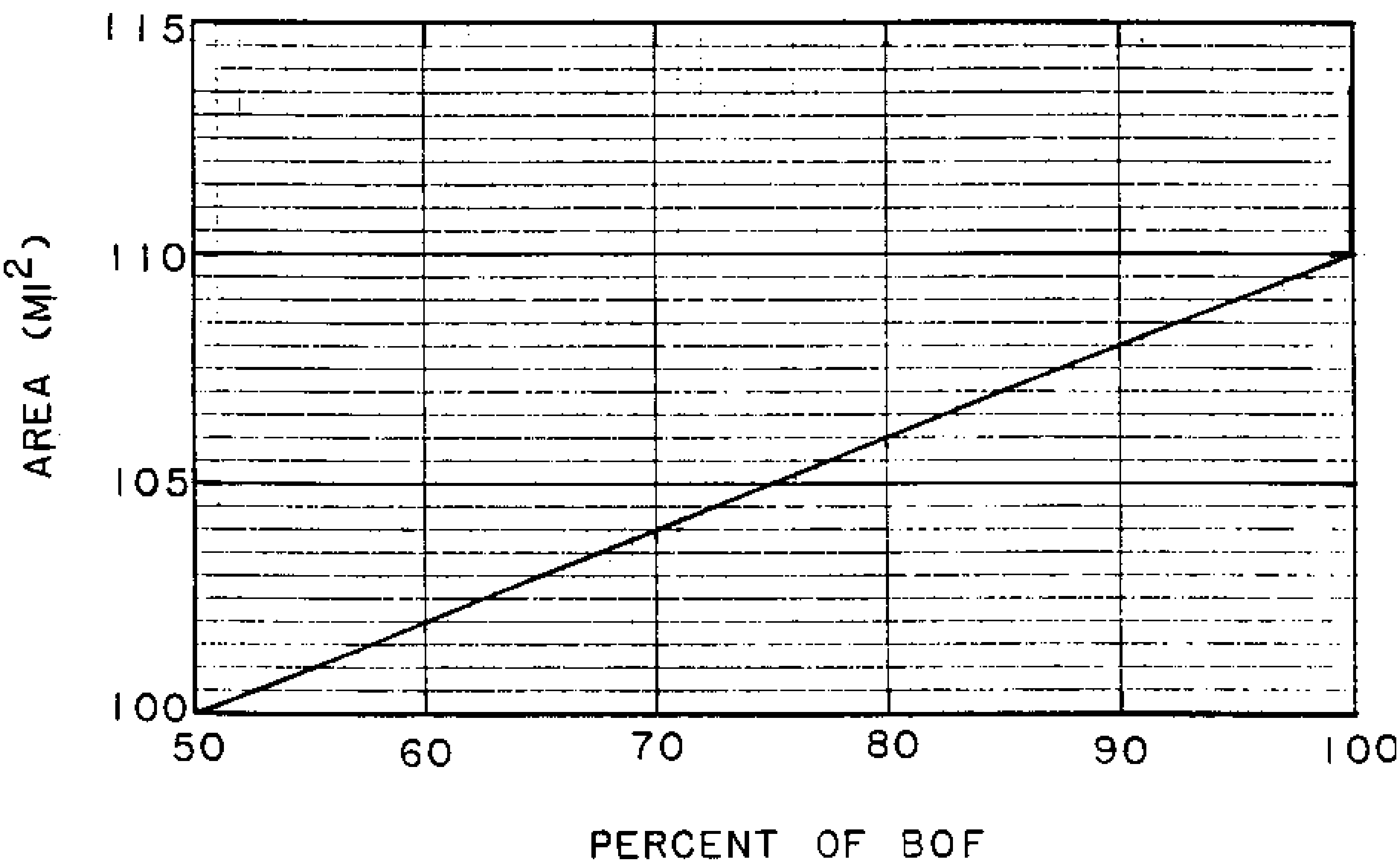


**Figure 70.--Adjustment applied to broadscale orographic factor (BOF) for areas near interface between large- and small-basin procedures.**

For this example, the TAF = TSF + BOF = 1.12 + .15 = 1.27 and rounds to 1.25. Additional examples of these factor determinations are given in chapter 5.

### 3.6 100-mi$^2$ Interface Differences

Application of the procedures described in sections 3.5.2 and 3.5.3 to develop PMP estimates for basins larger than 100 mi$^2$ has shown that, for basins close to 100 mi$^2$ in some regions, differences may be found between estimates developed from chapter 3 (large basin-procedure) and those from chapter 2 (small-basin procedure). Through a process of sample evaluation throughout the TVA region, it was noted that the differences occurred only in the mountainous east region for basins between 100 and 110 mi$^2$. Figure 70 has been developed to adjust the large basin factors applied to the various orographic classifications as depicted in figure 14 in the procedure (see sect. 5.4). The effects of figure 70 are primarily applicable to those drainages that are almost totally comprised of first upslopes in figure 14.

The application of the factors from figure 70 effectively reduces the observed differences at the interface area of 100 mi$^2$. However, because the small- and large-basin procedures are almost wholly independent, it is still likely that complete agreement will not occur between depth-duration estimates for areas in the vicinity of 100 mi$^2$. That is, for some computation, depth-area-duration relations developed by the small-basin procedure may give somewhat lower estimates at 100 mi$^2$ than estimates based on depth-area-duration relations using the large-basin procedure. At other times, the reverse is possible.

Since continuous depth-area-duration relations are needed for the areal distribution procedure discussed in section 4.3, the following recommendation is made. In such cases where discontinuous depth-area-duration relations occur at

100 $mi^2$, blend across this discontinuity with subjective smoothing. By this, it is meant to adjust whichever depth-area lines necessary to effect a smoothly varying depth-areal curve through areas affected. In general, it is anticipated that such smoothing can be limited to areas near 100 $mi^2$, but in some instances areal values up to 400 or 500 $mi^2$ may need to be adjusted. A demonstration of this recommendation is given in the example worked in section 5.5.2.

### 3.7 Summary

In drainages up to 3,000 $mi^2$, the primary rain producing storms in the Tennessee Valley are derived from combined decadent tropical storms and thunderstorms imbedded in general storms. The storm of September 28 to October 4, 1964 was a classic example of such a combined storm containing a large percentage of nonorographic rainfall. Features of such storms that are important to large rains in the region are:

1. High values of low-level moisture for the season of occurrence

2. Geographic fixing of repeating rain events

3. Thunderstorm involvement

This chapter presented a technique for determining the nonorographic component of PMP and TVA precipitation. The technique adjusts the depth-area-duration PMP or TVA precipitation data at Knoxville Airport, TN to the location of the drainage based on ratio maps (fig. 54 and 55).

The procedures used to develop the nonorographic precipitation do not adequately consider the effect of terrain roughness on the general storm. A terrain stimulation factor (TSF) based on the "rough" and "intermediate" terrain classifications is used to modify the nonorographic PMP and TVA precipitation. The TSF is first determined for an area of 100 $mi^2$ and then modified for the area size of the drainage.

In the mountainous eastern Tennessee Valley, the TSF must be further modified for orographic effects that are determined from consideration of five sets of indicators.

1. Mean annual nonorographic and orographic precipitation

2. 2-yr 24-hr precipitation

3. Highest monthly rains in subbasins

4. Small-basin PMP

5. Optimum wind directions

These indicators are used as guidance in modifying the TSF, based on a classification of slopes exposed to the optimum wind direction for a basin. The broadscale orographic factor is based on consideration of the proportion of the basin covered by primary and secondary upslopes and sheltered areas. The BOF is combined with a terrain stimulation factor to obtain the total adjustment factor (TAF), applied to the nonorographic computation of either PMP or TVA precipitation.

Finally, consideration is given to the situation where small differences arise between estimates at 100 mi$^2$ when derived from both the small-basin procedure and the procedure for basin areas of 100 to 3,000 mi$^2$. The recommended solution is to blend between the respective depth-area curves.

## 4. AREAL DISTRIBUTION OF PMP AND TVA PRECIPITATION

### 4.1 Introduction

HMR No. 45 (Schwarz and Helfert 1969) provided information on areal distribution of PMP and TVA precipitation and discussed the relative differences in application to basins in western and eastern TVA regions. More recently, HMR No. 52 (Hansen et al. 1982) provides a more comprehensive study of areal distribution for storm areas throughout the eastern United States. This study further developed and expanded the methodology provided by Schwarz and Helfert (1969). Of particular advantage from the HMR No. 52 studies was the work resulting in residual precipitation analysis. This feature essentially allows the user to evaluate the precipitation that falls outside the PMP storm area but concurrently with the PMP storm. Such information offers numerous benefits to hydrologic analyses.

A decision was made in the present study to use the HMR No. 52 procedures for areal distribution of storm-average depths of nonorographic PMP and TVA precipitation in the Tennessee Valley drainages. Application of these procedures in this report provides the technique for converting storm-centered information to basin-centered information. For convenience, the necessary steps and figures from HMR No. 52 required for making these computations are reproduced in this chapter. Reference should be made to HMR No. 52 for discussions concerning the development of the information provided in this chapter.

While the information in HMR No. 52 applies specifically to the concept of nonorographic PMP, the same concepts and applications will be used in this study regarding nonorographic TVA precipitation components. In addition, the conversion factors of 0.58, 0.55 and 0.53 developed in the small-basin procedure to obtain rough, intermediate and smooth TVA precipitation, respectively, from PMP values, will be applied in this chapter as well. Adoption of these conversions provided a first approximation technique for deriving the areal distribution of TVA precipitation. Specifically, if the areal distribution of TVA precipitation is required, first determine the incremental isohyetal labels for PMP. Then, apply the respective conversion factor according to whether the primary basin is mostly rough, intermediate, or smooth. Clarification of this procedure will be given in the examples provided in chapter 5.

The procedures and idealized isohyetal pattern in HMR No. 52 apply to nonorographic PMP storms only, and therefore can be used without modification for basin studies in the western portion of the Tennessee Valley (refer to fig. 1). However, in the eastern portion of the region, the pattern is modified by the effects of terrain, and section 4.3.2 discusses the methods developed for this study.

The following definitions are useful in considering the areal distribution of storm rainfalls. Refer to figure 71 for additional clarification:

PMP storm pattern The isohyetal pattern that encloses the PMP area plus the isohyets of residual precipitation outside the PMP portion of the pattern. The standard isohyetal pattern covering the basin and concurrent basins of interest is shown in figure 72.

PMP storm area The area of the PMP storm that provides the maximum volume of precipitation over the drainage being considered. In figure 71, the pattern of solid isohyets.

Residual precipitation The precipitation that falls outside the PMP storm area, regardless of the size of the drainage. Because of the irregular shape of the drainage, or because of the choice of a PMP pattern smaller in area than the area of the drainage, some of the residual precipitation can fall within the drainage. Thus, in many applications the maximum volume of precipitation in a drainage comes from both the PMP storm (the solid isohyets in fig. 71) and residual precipitation (the dashed isohyets in fig. 71).

Concurrent precipitation The precipitation that falls outside the drainage of interest. Concurrent precipitation can be composed of both PMP and residual precipitation. In figure 71, subdrainage B (unhatched) is a concurrent drainage to the drainage of interest (subdrainage A). Precipitation falling in subdrainage B is thus concurrent precipitation. Concurrent precipitation can be determined for any number of drainages surrounding the drainage of primary interest.

Isohyetal orientation The orientation (direction from north) of the major axis of the elliptical pattern of PMP. The term is used in this study also to define the orientation of precipitation patterns of major storms when approximated by elliptical patterns of best fit. To avoid the need for specifying dual orientations a rule has been devised in HMR No. 52 to identify orientations by directions between 135 and 315 degrees, only.

Storm-centered area-averaged PMP The values obtained from this report corresponding to the area of the PMP portion of the PMP storm pattern. In this report, all references to PMP estimates or to incremental PMP infer storm-area averaged PMP.

Drainage or Basin-averaged PMP After the PMP storm pattern has been distributed across a specific drainage and the computational procedure of this report applied, we obtain drainage-averaged PMP estimates. These values include that portion of the PMP storm pattern that occur over the drainage, both PMP and residual.

## 4.2 Isohyetal Pattern

### 4.2.1. Standard isohyetal pattern

Figure 72 shows the standard elliptical isohyetal pattern used in this study. The ratio of major to minor axis in this pattern is 2.5 to 1 in keeping with the results of a study of major storms throughout the eastern United States. The ratio of major to minor axes is sometimes referred to as the shape ratio. In HMR No. 52, the storm sample was divided into regional samples in an effort to detect regional variations, but none was found. This pattern is given for a map scale

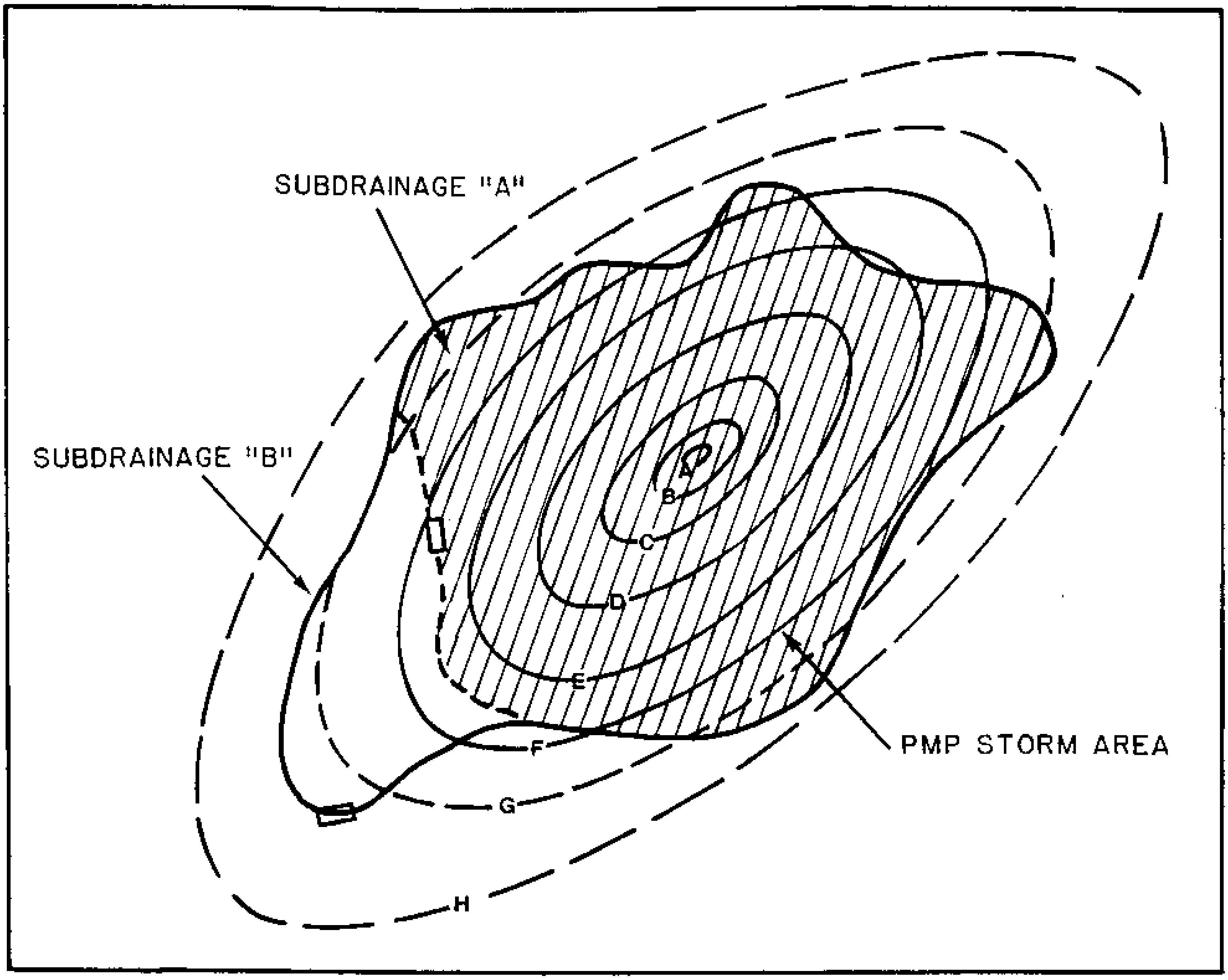


**Figure 71.--Schematic diagram of idealized PMP storm pattern placed over a subdrainage ("A") illustrating the isohyets that cover a concurrent subdrainage ("B"). Solid isohyets represent PMP pattern area; dashed isohyets represent residual precipitation.**

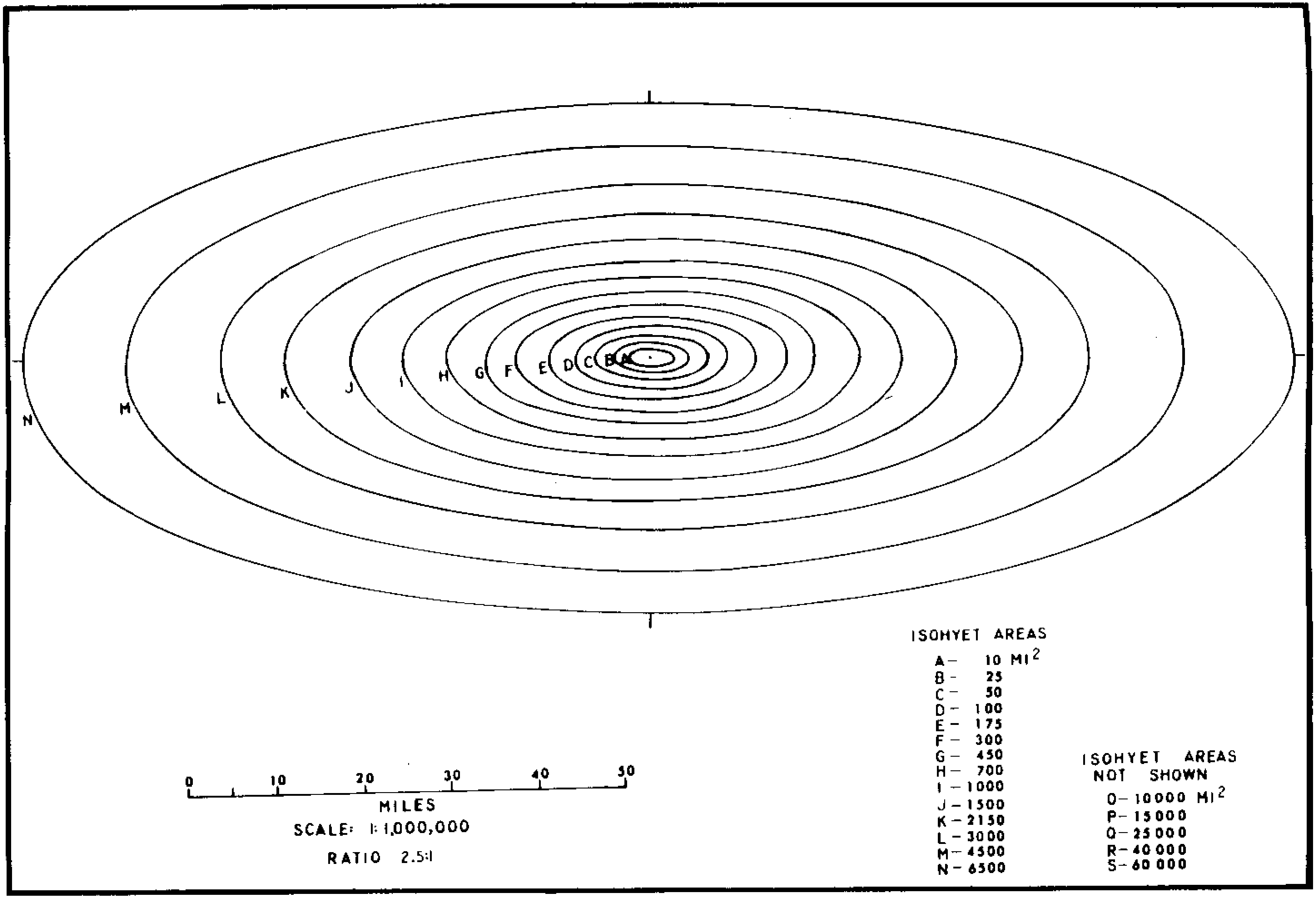


**Figure 72.**--Standard isohyetal pattern recommended for spatial distribution of nonorographic PMP over the Tennessee River basin (scale 1:1,000,000).

**Table 11.--Axial distances (mi) for construction of an elliptical isohyetal pattern for standard isohyet areas with a 2.5 shape ratio (Complete four quadrants to obtain pattern).**

| Isohyet label | Standard isohyets enclosed area ($mi^2$) | Incremental area ($mi^2$) | Radial axis (deg.)* 0 | 15 | 30 | 45 | 60 | 90 |
|---|---|---|---|---|---|---|---|---|
| A | 10 | 10 | 2.820 | 2.426 | 1.854 | 1.481 | 1.269 | 1.128 |
| B | 25 | 15 | 4.460 | 3.836 | 2.933 | 2.342 | 2.007 | 1.784 |
| C | 50 | 25 | 6.308 | 5.426 | 4.148 | 3.313 | 2.839 | 2.523 |
| D | 100 | 50 | 8.920 | 7.672 | 5.866 | 4.685 | 4.014 | 3.568 |
| E | 175 | 75 | 11.801 | 10.150 | 7.758 | 6.198 | 5.310 | 4.720 |
| F | 300 | 125 | 15.451 | 13.289 | 10.160 | 8.115 | 6.953 | 6.180 |
| G | 450 | 150 | 18.924 | 16.276 | 12.444 | 9.939 | 8.516 | 7.569 |
| H | 700 | 250 | 23.602 | 20.301 | 15.521 | 12.397 | 10.622 | 9.441 |
| I | 1,000 | 300 | 28.209 | 24.263 | 18.550 | 14.816 | 12.965 | 11.284 |
| J | 1,500 | 500 | 34.549 | 29.717 | 22.720 | 18.146 | 15.549 | 13.820 |
| K | 2,150 | 650 | 41.363 | 35.577 | 27.200 | 21.725 | 18.614 | 16.545 |
| L | 3,000 | 850 | 48.860 | 42.026 | 32.130 | 25.662 | 21.989 | 19.544 |
| M | 4,500 | 1,500 | 59.841 | 51.470 | 39.351 | 31.430 | 26.930 | 23.936 |
| N | 6,500 | 2,000 | 71.920 | 61.860 | 47.294 | 37.774 | 32.366 | 28.768 |
| O | 10,000 | 3,500 | 89.206 | 76.728 | 58.661 | 46.853 | 40.145 | 35.682 |
| P | 15,000 | 5,000 | 109.225 | 93.973 | 71.846 | 57.383 | 49.168 | 43.702 |
| Q | 25,000 | 10,000 | 141.047 | 121.318 | 92.752 | 74.082 | 63.476 | 56.419 |
| R | 40,000 | 15,000 | 178.412 | 153.456 | 17.323 | 93.707 | 80.292 | 71.365 |
| S | 60,000 | 20,000 | 218.510 | 187.945 | 143.691 | 114.767 | 98.337 | 87.404 |

* 0° radial axis = semi-major axis
90° radial axis = semi-minor axis

To aid in construction of any additional isohyets, we provide the following relations, where a is the semi-major axis, b is the semi-minor axis, and A is area of the ellipse.

For this study, $a = 2.5b$

For a specific area, A, $b = \left(\frac{A}{2.5\pi}\right)^{1/2}$

Radial equation of ellipse $r^2 = \frac{a^2 b^2}{a^2 \sin^2\theta + b^2 \cos^2\theta}$

where r = distance along a radial at an angle θ to the major axis of 1:1,000,000, since it was determined in recent surveys that this scale was appropriate to most user needs. The pattern in figure 72 contains isohyets labeled A (10 $mi^2$) to N (6,500 $mi^2$). These are referred to as standard isohyets and in HMR No. 52 the pattern was evaluated out to 60,000 $mi^2$ (additional isohyets not shown are: 10,000, 15,000, 25,000, 40,000 and 60,000 $mi^2$). Table 11 provides information used in constructing the isohyetal pattern in figure 72 and to develop the larger isohyets. Basic equations are included in case intermediate isohyets are required.

### 4.2.2 Isohyetal pattern orientation

HMR No. 52 evaluated a question that has been posed in a number of other hydrometeorological reports. The question was: Is PMP likely to occur from an optimum set of meteorological conditions? If so, does this result in a preferred orientation of the rainfall pattern? The concept says that at any particular location, there is a preferred direction or range of directions that represent the combined interaction of moisture inflow, upper level winds and other meteorological factors important in a PMP event. Major storm rainfall patterns were reviewed and figure 73 shows the general conclusions made in HMR No. 52. A range of "preferred" orientations was accepted as ±40° from those shown in figure 73. Figure 73 shows the agreement between selected major storm orientations and the analysis of preferred directions.

The concept of preferred orientations implies that if an orientation was selected that was outside the range of ± 40° from that shown on figure 73, the storm-averaged level of PMP at that location would be reduced. A model was postulated as presented in figure 74 that enables determination of the degree of reduction applicable to PMP for pattern orientations that differ between 40 and 90 degrees from the preferred orientation. In this figure, the reduction shown is dependent upon pattern area size. For pattern areas less than 300 $mi^2$, there is no reduction since it was formulated in HMR No. 52 that all small-area storm orientations were equally likely within current knowledge. A maximum reduction of 15 percent applies only to areas greater than 3,000 $mi^2$, when the orientation difference from that shown in figure 73 is more than ± 65 degrees.

### 4.2.3 Isohyetal Percentages

In the HMR No. 52 study a procedure was developed which permitted computations of individual isohyetal rainfall amounts for PMP storm areas of various sizes. The results are summarized in a set of tables presented in tables 12 to 15. Table 12 provides percentage values for the standard isohyetal areas for the 1st 6-hr increment (largest 6-hr amount) in a 72-hr storm. Tables 13 and 14 provide similar information for the 2nd and 3rd 6-hr increments, respectively. Table 15 gives percentages that apply to the 4th through 12th 6-hr increments. Note that in tables 12-15, storm areas intermediate to the standard areas in figure 72 have been included for convenience. In table 15, percentages are given only for isohyets of the residual precipitation, since it was accepted in HMR No. 52 that within the PMP storm, a uniform distribution (i.e., a flat value) would prevail for increments beyond the three largest 6-hr amounts.

The information in tables 12 to 15 came from nomograms developed in HMR No. 52 that uniquely provide values (in percent of the 6-hr incremental PMP amount) for any PMP storm area size up to 20,000 $mi^2$. These nomograms are reproduced in figures 75 to 78 in the event that they are needed for development of percentages

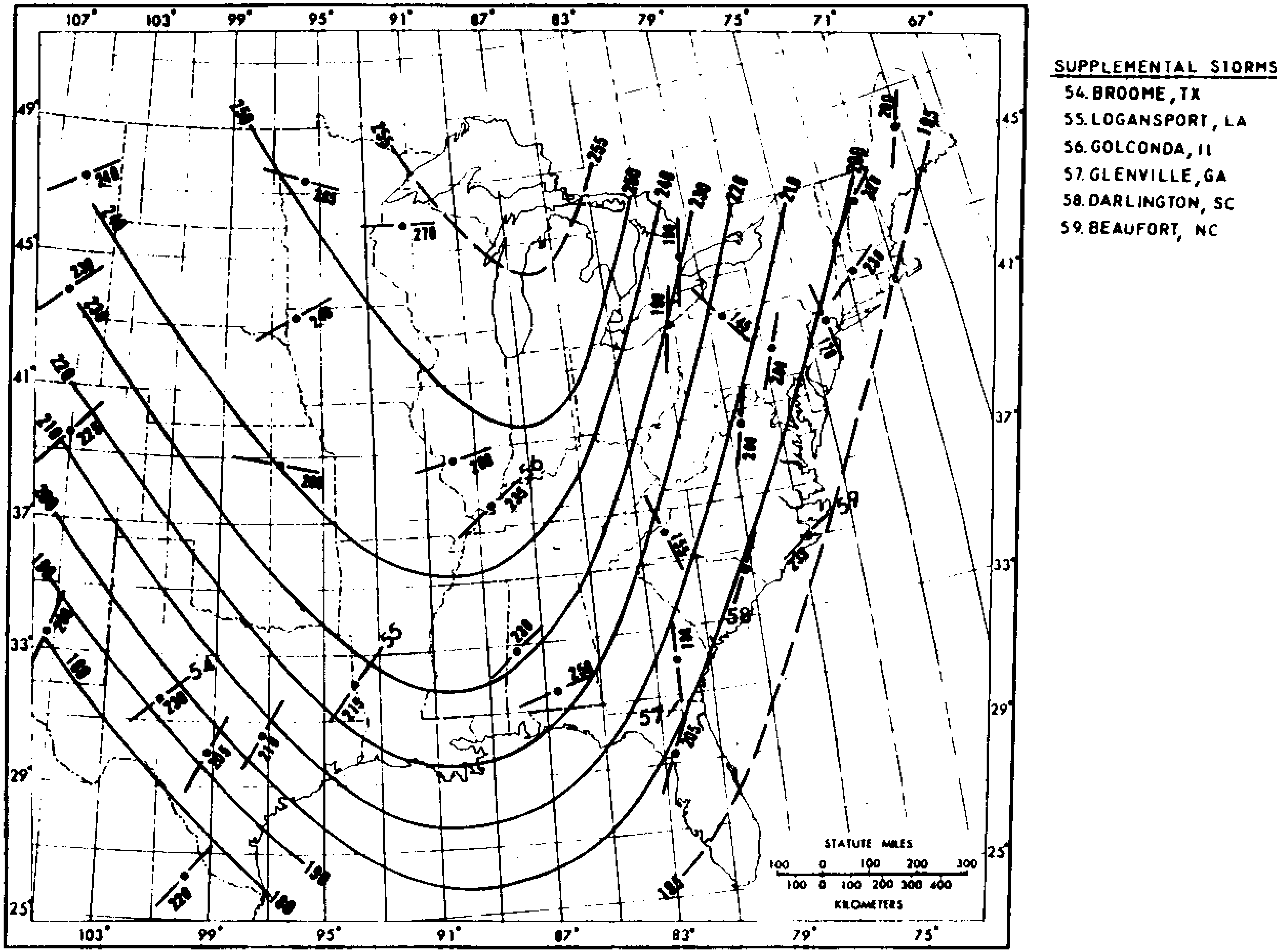


Figure 73.--Analysis of isohyetal orientations for selected major storms adopted as a recommended orientation for PMP within ±40° (Hansen et al. 1982).

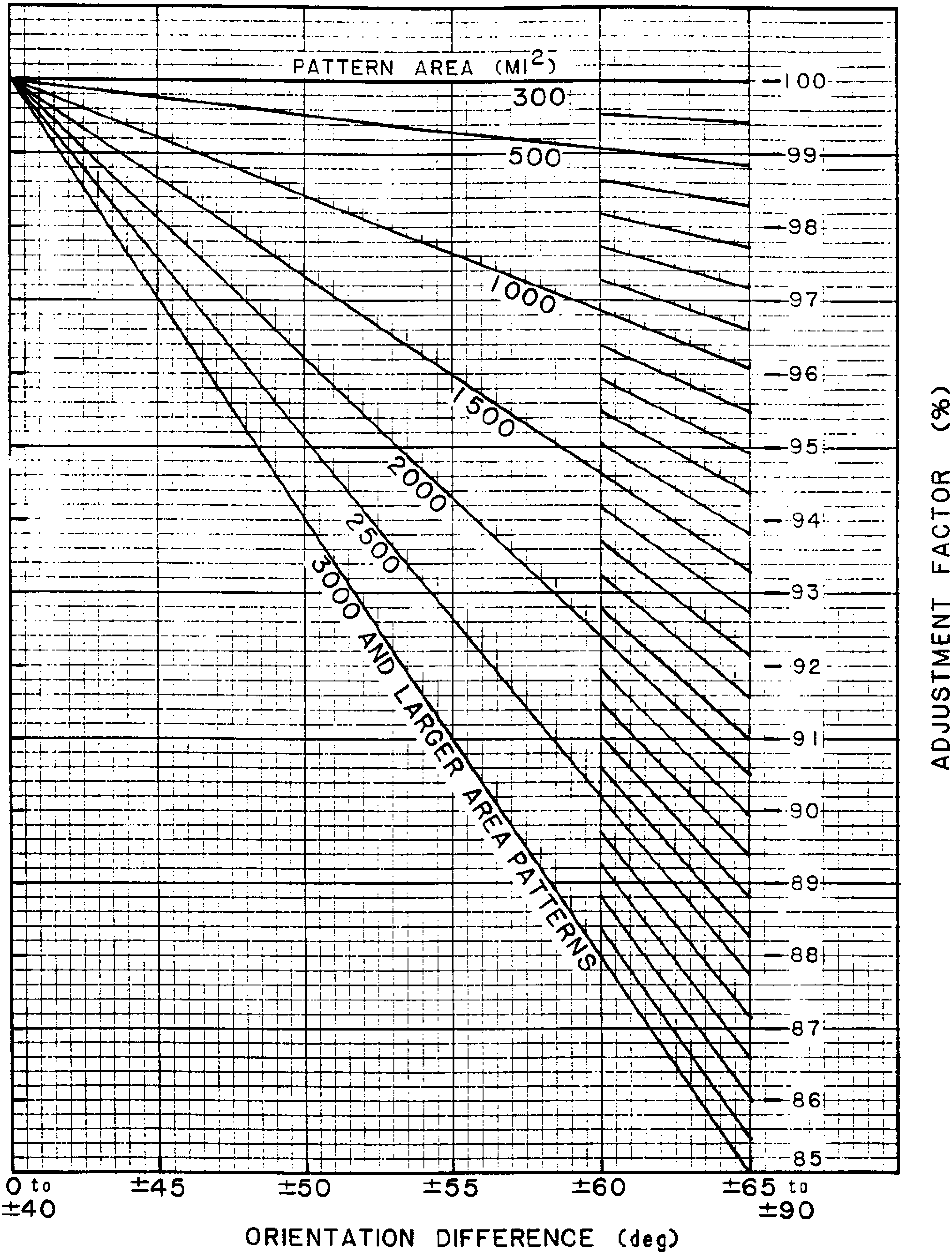


**Figure 74.**--Model for determining the adjustment factor to apply to isohyet values as a result of placing the pattern in figure 72 at an orientation differing from that given in figure 73 by more than 40°, for a specific location (Hansen et al. 1982).

**Table 12.--1st 6-hr nomogram values at selected area sizes (Hansen et al. 1982)**

| Isohyet | Storm Area (mi $^2$) size<br>10 | 17 | 25 | 35 | 50 | 75 | 100 | 140 | 175 | 220 | 300 | 360 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Values in Percent | | | | | | | | | | | |
| A | 100* | 101 | 102 | 104 | 106 | 109 | 112 | 116 | 119 | 122 | 126 | 129 |
| B | 64 | 78 | 95* | 97 | 99 | 102 | 105 | 108 | 111 | 114 | 118 | 121 |
| C | 48 | 58 | 67 | 77 | 92* | 95 | 98 | 101 | 103 | 106 | 110 | 113 |
| D | 38 | 46 | 52 | 59 | 66 | 77 | 90* | 93 | 96 | 99 | 103 | 105 |
| E | 30 | 37 | 43 | 48 | 54 | 62 | 68 | 78 | 89* | 92 | 96 | 98 |
| F | 24 | 30 | 34 | 39 | 44 | 50 | 55 | 61 | 66 | 73 | 88* | 90 |
| G | 19 | 24 | 28 | 32 | 35 | 40 | 44 | 49 | 53 | 58 | 65 | 73 |
| H | 14 | 19 | 22 | 25 | 28 | 32 | 35 | 39 | 42 | 46 | 51 | 56 |
| I | 10 | 14 | 17 | 19 | 22 | 26 | 28 | 32 | 34 | 37 | 42 | 45 |
| J | 6 | 9 | 12 | 14 | 16 | 19 | 21 | 24 | 26 | 28 | 32 | 35 |
| K | 2 | 5 | 7 | 9 | 11 | 14 | 16 | 18 | 20 | 22 | 25 | 27 |
| L | 0 | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 |
| M | | 0 | 0 | 1 | 3 | 5 | 6 | 8 | 9 | 10 | 12 | 13 |
| N | | | | 0 | 0 | 0 | 1 | 2 | 3 | 4 | 6 | 7 |
| O | | | | | | | 0 | 0 | 0 | 0 | 1 | 2 |
| P | | | | | | | | | | | 0 | 0 |

*Indicates cusp

**Table 12.--1st 6-hr nomogram values at selected area sizes (Continued)**

| Isohyet | Storm Area (mi $^2$) size<br>450 | 560 | 700 | 850 | 1000 | 1200 | 1500 | 1800 | 2150 | 2600 | 3000 | 3800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 132 | 136 | 140 | 145 | 149 | 155 | 162 | 169 | 176 | 184 | 191 | 203 |
| B | 124 | 128 | 132 | 136 | 140 | 145 | 152 | 158 | 165 | 172 | 179 | 189 |
| C | 116 | 120 | 124 | 128 | 131 | 136 | 142 | 147 | 154 | 160 | 166 | 176 |
| D | 108 | 111 | 115 | 119 | 122 | 126 | 132 | 137 | 142 | 148 | 154 | 163 |
| E | 101 | 104 | 107 | 110 | 113 | 116 | 122 | 126 | 131 | 137 | 142 | 150 |
| F | 93 | 95 | 98 | 101 | 104 | 107 | 112 | 117 | 122 | 127 | 132 | 140 |
| G | 86* | 89 | 92 | 94 | 97 | 100 | 105 | 108 | 113 | 118 | 122 | 130 |
| H | 63 | 72 | 84* | 87 | 89 | 92 | 96 | 99 | 103 | 108 | 112 | 119 |
| I | 50 | 56 | 63 | 72 | 82* | 85 | 88 | 91 | 95 | 99 | 102 | 108 |
| J | 38 | 43 | 48 | 54 | 60 | 68 | 80* | 83 | 86 | 89 | 92 | 98 |
| K | 30 | 33 | 36 | 40 | 44 | 49 | 56 | 64 | 77* | 80 | 83 | 89 |
| L | 23 | 25 | 27 | 30 | 32 | 35 | 41 | 46 | 52 | 62 | 74* | 79 |
| M | 15 | 16 | 18 | 19 | 21 | 23 | 26 | 29 | 33 | 38 | 44 | 56 |
| N | 8 | 9 | 10 | 11 | 12 | 14 | 16 | 18 | 20 | 22 | 25 | 31 |
| O | 3 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 13 | 15 |
| P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 4 | 6 |
| Q | | | | | | | | 0 | 0 | 0 | 0 | 0 |

*Indicates cusp

**Table 12.--1st 6-hr nomogram values at selected area sizes (Continued)**

| Isohyet | Storm Area (mi $^2$) size 4500 | 5500 | 6500 | 8000 | 10000 | 12000 | 15000 | 18000 | 20000 |
|---|---|---|---|---|---|---|---|---|---|
| A | 212 | 223 | 233 | 247 | 262 | 274 | 290 | 304 | 312 |
| B | 198 | 209 | 218 | 230 | 243 | 255 | 271 | 283 | 291 |
| C | 184 | 194 | 203 | 214 | 227 | 238 | 253 | 264 | 271 |
| D | 170 | 180 | 187 | 198 | 209 | 219 | 232 | 242 | 248 |
| E | 157 | 166 | 174 | 183 | 194 | 203 | 214 | 224 | 229 |
| F | 146 | 153 | 160 | 169 | 178 | 186 | 196 | 205 | 210 |
| G | 135 | 142 | 148 | 157 | 166 | 174 | 183 | 192 | 197 |
| H | 124 | 131 | 137 | 144 | 152 | 159 | 168 | 176 | 181 |
| I | 113 | 119 | 125 | 132 | 140 | 147 | 156 | 164 | 168 |
| J | 103 | 108 | 113 | 120 | 128 | 135 | 143 | 150 | 154 |
| K | 93 | 98 | 103 | 110 | 117 | 123 | 131 | 138 | 142 |
| L | 83 | 88 | 93 | 99 | 107 | 113 | 120 | 127 | 131 |
| M | 71* | 76 | 81 | 87 | 93 | 99 | 106 | 113 | 117 |
| N | 37 | 48 | 70* | 75 | 82 | 87 | 94 | 101 | 104 |
| O | 19 | 23 | 29 | 40 | 68* | 73 | 80 | 86 | 89 |
| P | 8 | 10 | 13 | 18 | 26 | 38 | 65* | 71 | 74 |
| Q | 0 | 0 | 1 | 3 | 7 | 11 | 18 | 28 | 36 |
| R | | | 0 | 0 | 0 | 0 | 2 | 6 | 8 |
| S | | | | | | | 0 | 0 | 0 |

*Indicates cusp

**Table 13.--2nd 6-hr nomogram values at selected area sizes (Hansen et al. 1982)**

| Isohyet | Storm Area (mi $^2$) size 10 | 17 | 25 | 35 | 50 | 75 | 100 | 140 | 175 | 220 | 300 | 360 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 100* | 102 | 103 | 104 | 105.5 | 107 | 108 | 109 | 110 | 110.5 | 111.5 | 112 |
| B | 64 | 81.5 | 98* | 99 | 100.5 | 102 | 103 | 104 | 105 | 106 | 107 | 108 |
| C | 48 | 61 | 72 | 82 | 96.5* | 98 | 99 | 100.5 | 101.5 | 102.5 | 103.5 | 104 |
| D | 39 | 50 | 59 | 66.5 | 76 | 86 | 95* | 96.5 | 97.5 | 98.5 | 100 | 101 |
| E | 30 | 40 | 48 | 54.5 | 62.5 | 72 | 79 | 88 | 95* | 96 | 97.5 | 98.5 |
| F | 24 | 32 | 39 | 44.5 | 51 | 59.5 | 65 | 73 | 79 | 85 | 95* | 96 |
| G | 20 | 27 | 32.5 | 37.5 | 43.5 | 50 | 55 | 62 | 66.5 | 72 | 80 | 85 |
| H | 14 | 20.5 | 26 | 30.5 | 36 | 42 | 47 | 52.5 | 56.5 | 61 | 67.5 | 72 |
| I | 10 | 15.5 | 20 | 24 | 29 | 34.5 | 38.5 | 43.5 | 47 | 51 | 57 | 61 |
| J | 7 | 12 | 15.5 | 19 | 23 | 27.5 | 31 | 35 | 38.5 | 42 | 47 | 50 |
| K | 3 | 7 | 10.5 | 13.5 | 17 | 21 | 24 | 27.5 | 30 | 33 | 37.5 | 40.5 |
| L | 0 | 1.5 | 5 | 7.5 | 11 | 14.5 | 17 | 20.5 | 23 | 26 | 30 | 33 |
| M | | 0 | 0 | 1 | 4 | 7 | 9 | 12 | 14.5 | 17 | 20.5 | 23 |
| N | | | | 0 | 0 | 0 | 1 | 3.5 | 5 | 7.5 | 10 | 12 |
| O | | | | | | | 0 | 0 | 0 | 0 | 1 | 3 |
| P | | | | | | | | | | | 0 | 0 |

*Indicates cusp

Table 13.--2nd 6-hr nomogram values at selected area sizes (Continued)

| Isohyet | Storm Area ($mi^2$) size: 450 | 560 | 700 | 850 | 1000 | 1200 | 1500 | 1800 | 2150 | 2600 | 3000 | 3800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 113 | 114 | 114.5 | 115 | 116 | 116.5 | 117 | 118 | 118.5 | 119 | 119.5 | 120.5 |
| B | 109 | 109.5 | 110 | 111 | 112 | 112.5 | 113 | 114 | 114.5 | 115.5 | 116 | 117 |
| C | 105 | 106 | 107 | 107.5 | 108.5 | 109 | 110 | 110.5 | 111 | 112 | 112.5 | 113.5 |
| D | 102 | 102.5 | 104 | 104.5 | 105 | 106 | 107 | 108 | 108.5 | 109.5 | 110 | 111 |
| E | 99.5 | 100.5 | 101 | 102 | 103 | 104 | 105 | 105.5 | 106.5 | 107 | 108 | 109 |
| F | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 104.5 | 105.5 | 106 | 107 |
| G | 95* | 96 | 97 | 98 | 99 | 99.5 | 100.5 | 101.5 | 102 | 103 | 104 | 105 |
| H | 77.5 | 85 | 95* | 96 | 97 | 97.5 | 99 | 99.5 | 100 | 101 | 102 | 103 |
| I | 66 | 71.5 | 78 | 85 | 95* | 96 | 97 | 98 | 99 | 99.5 | 100.5 | 101.5 |
| J | 54.5 | 60 | 65.5 | 71 | 76 | 82.5 | 95.5* | 96 | 97 | 98 | 99 | 100 |
| K | 44.5 | 49 | 54 | 58.5 | 63 | 68 | 75.5 | 83 | 96* | 96.5 | 97 | 98 |
| L | 36.5 | 40 | 44 | 48 | 51 | 55 | 60.5 | 66 | 73 | 83 | 96* | 97 |
| M | 25.5 | 28.5 | 32 | 35 | 38 | 41 | 45 | 49.5 | 54 | 60.5 | 67 | 81 |
| N | 14 | 17 | 19.5 | 22 | 24 | 27 | 31 | 34 | 37.5 | 41.5 | 45 | 52.5 |
| O | 4.5 | 6.5 | 9 | 11 | 12.5 | 14.5 | 17 | 19.5 | 22 | 25.5 | 28.5 | 34 |
| P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.5 | 4 | 7 | 9 | 13.5 |
| Q | | | | | | | | 0 | 0 | 0 | 0 | 0 |

*Indicates cusp

Table 13.--2nd 6-hr nomogram values at selected area sizes (Continued)

| Isohyet | Storm Area ($mi^2$) size: 4500 | 5500 | 6500 | 8000 | 10000 | 12000 | 15000 | 18000 | 20000 |
|---|---|---|---|---|---|---|---|---|---|
| A | 121 | 122 | 122 | 123 | 124 | 124.5 | 125 | 126 | 126 |
| B | 117 | 118 | 119 | 120 | 120.5 | 121 | 122 | 122.5 | 123 |
| C | 114 | 115 | 115.5 | 116.5 | 117 | 118 | 119 | 119.5 | 120 |
| D | 112 | 112.5 | 113 | 114 | 115 | 116 | 117 | 118 | 118 |
| E | 109.5 | 110.5 | 111 | 112 | 113 | 114 | 115 | 116 | 116 |
| F | 108 | 108.5 | 109 | 110 | 111 | 112 | 113 | 113.5 | 114 |
| G | 105.5 | 106.5 | 107 | 108 | 109 | 110 | 111 | 112 | 112 |
| H | 103.5 | 104.5 | 105 | 106 | 107 | 108 | 109 | 110 | 110 |
| I | 102 | 103 | 104 | 104.5 | 105.5 | 106.5 | 107 | 108 | 108.5 |
| J | 100.5 | 101.5 | 102 | 103 | 104 | 105 | 106 | 106.5 | 107 |
| K | 99 | 100 | 100.5 | 101.5 | 102.5 | 103 | 104 | 105 | 105 |
| L | 97.5 | 98.5 | 99 | 100 | 101 | 102 | 102.5 | 103.5 | 104 |
| M | 96* | 97 | 97.5 | 98.5 | 99 | 100 | 101 | 102 | 102 |
| N | 59 | 72.5 | 95.5* | 96 | 97 | 98 | 99 | 99.5 | 100 |
| O | 39 | 46 | 52.5 | 66 | 95* | 96 | 97 | 97.5 | 98 |
| P | 17 | 22 | 27.5 | 37 | 50 | 64 | 96* | 96.5 | 97 |
| Q | 0 | 0 | 1 | 6 | 14 | 21 | 34 | 47 | 55 |
| R | | 0 | | 0 | 0 | 0 | 0 | 4.5 | 7 |
| S | | | | | | | | | 0 |

*Indicates cusp

**Table 14.--3rd 6-hr nomogram values at selected area sizes (Hansen et al. 1982)**

| Isohyet | Storm Area (mi$^2$) size: 10 | 17 | 25 | 35 | 50 | 75 | 100 | 140 | 175 | 220 | 300 | 360 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 100* | 100.6 | 101 | 101.3 | 101.6 | 102 | 102.3 | 102.6 | 102.8 | 103.1 | 103.4 | 103.6 |
| B | 65 | 83.5 | 99* | 99.4 | 99.8 | 100.3 | 100.7 | 101 | 101.3 | 101.5 | 101.9 | 102.1 |
| C | 48 | 63 | 74.5 | 85.5 | 98.5* | 99 | 99.3 | 99.7 | 100 | 100.3 | 100.7 | 100.9 |
| D | 39 | 51 | 60.5 | 69 | 78.5 | 90 | 98.6* | 99 | 99.2 | 99.5 | 99.8 | 100.1 |
| E | 30 | 40 | 48.5 | 55.5 | 63 | 73.5 | 81.5 | 92 | 98.8* | 99 | 99.3 | 99.5 |
| F | 24 | 33 | 40 | 46.5 | 53.5 | 61.5 | 68 | 76.5 | 83 | 89 | 99.0* | 99.2 |
| G | 20 | 28 | 34 | 39.5 | 46 | 53 | 59 | 66 | 71 | 77 | 86 | 92 |
| H | 14 | 21 | 27 | 32.5 | 37.5 | 44 | 49 | 55 | 59.5 | 64 | 72 | 76.5 |
| I | 10 | 16.5 | 21.5 | 26.5 | 31.5 | 37.5 | 42 | 47.5 | 51 | 55.5 | 62 | 66 |
| J | 6.5 | 12.5 | 17 | 21 | 26 | 31.5 | 35.5 | 40.5 | 44 | 47.5 | 53 | 56 |
| K | 3 | 7.5 | 11.5 | 15 | 19.5 | 24.5 | 28 | 32.5 | 35 | 38.5 | 43 | 46 |
| L | 0 | 1.5 | 5 | 8.5 | 12 | 16.5 | 20 | 24 | 26.5 | 29.5 | 33.5 | 36 |
| M | | 0 | 0 | 1 | 4 | 8.5 | 11.5 | 15 | 18 | 20.5 | 24.5 | 27 |
| N | | | | 0 | 0 | 0 | 1 | 4.5 | 7 | 10 | 14 | 16 |
| O | | | | | | | 0 | 0 | 0 | 0 | 2 | 4 |
| P | | | | | | | | | | | 0 | 0 |

*Indicates cusp

**Table 14.--3rd 6-hr nomogram values at selected area sizes (Continued)**

| Isohyet | Storm Area (mi$^2$) size: 450 | 560 | 700 | 850 | 1000 | 1200 | 1500 | 1800 | 2150 | 2600 | 3000 | 3800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 103.8 | 104 | 104.2 | 104.4 | 104.6 | 104.7 | 105 | 105.2 | 105.3 | 105.5 | 105.7 | 105.8 |
| B | 102.4 | 102.7 | 102.9 | 103.2 | 103.3 | 103.5 | 103.8 | 104 | 104.2 | 104.4 | 104.6 | 104.8 |
| C | 101.2 | 101.5 | 101.7 | 102 | 102.3 | 102.5 | 102.7 | 102.9 | 103.2 | 103.4 | 103.5 | 103.8 |
| D | 100.3 | 100.6 | 100.8 | 101.1 | 101.3 | 101.5 | 101.7 | 102 | 102 | 102.4 | 102.5 | 102.8 |
| E | 99.8 | 100 | 100.2 | 100.4 | 100.6 | 100.8 | 101 | 101.2 | 101.3 | 101.5 | 101.7 | 101.9 |
| F | 99.5 | 99.7 | 99.9 | 100.1 | 100.3 | 100.4 | 100.7 | 100.8 | 101 | 101.2 | 101.3 | 101.5 |
| G | 99.2* | 99.4 | 99.6 | 99.7 | 99.9 | 100 | 100.3 | 100.4 | 100.6 | 100.7 | 100.9 | 101.1 |
| H | 84 | 91 | 99.2* | 99.4 | 99.6 | 99.7 | 100 | 100.1 | 100.3 | 100.4 | 100.5 | 100.7 |
| I | 71 | 77.5 | 85 | 92 | 99.3* | 99.5 | 99.7 | 99.8 | 100 | 100.1 | 100.2 | 100.5 |
| J | 60 | 64.5 | 70.5 | 76.5 | 82.5 | 89.5 | 99.4* | 99.5 | 99.7 | 99.8 | 99.9 | 100.1 |
| K | 50 | 54 | 58.5 | 62.5 | 67 | 72.5 | 81 | 89 | 99.5* | 99.5 | 99.6 | 99.8 |
| L | 39.5 | 43 | 47 | 50.5 | 54 | 58.5 | 65.5 | 72.5 | 80.5 | 90.5 | 99.3* | 99.5 |
| M | 30 | 33 | 37 | 40 | 43 | 46.5 | 51.5 | 56.5 | 61 | 69 | 76 | 88.5 |
| N | 19 | 22.5 | 25.5 | 28.5 | 31 | 34 | 38 | 42 | 46.5 | 52 | 57 | 67 |
| O | 7 | 10 | 13 | 15.5 | 17.5 | 20.5 | 24 | 27 | 30.5 | 34 | 37.5 | 43.5 |
| P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 5.5 | 9 | 12 | 16.5 |
| Q | | | | | | | | | 0 | 0 | 0 | 0 |

*Indicates cusp

Table 14.--3rd 6-hr nomogram values at selected area sizes (Continued)

| Isohyet | Storm Area ($mi^2$) size 4500 | 5500 | 6500 | 8000 | 10000 | 12000 | 15000 | 18000 | 20000 |
|---|---|---|---|---|---|---|---|---|---|
| A | 106 | 106.2 | 106.4 | 106.6 | 106.8 | 107 | 107.2 | 107.4 | 107.5 |
| B | 105 | 105.3 | 105.5 | 105.7 | 106 | 106.2 | 106.5 | 106.7 | 106.8 |
| C | 104 | 104.3 | 104.5 | 104.8 | 105 | 105.3 | 105.5 | 105.8 | 105.9 |
| D | 103.1 | 103.2 | 103.5 | 103.7 | 104 | 104.2 | 104.4 | 104.6 | 104.7 |
| E | 102.1 | 102.3 | 102.5 | 102.7 | 101.9 | 102.1 | 102.3 | 102.4 | 102.5 |
| F | 101.7 | 101.8 | 102 | 102.2 | 102.4 | 102.6 | 102.8 | 103 | 103 |
| G | 101.2 | 101.4 | 101.5 | 101.7 | 101.9 | 102.1 | 102.3 | 102.4 | 102.5 |
| H | 100.9 | 101.1 | 101.2 | 101.4 | 101.6 | 101.8 | 102 | 102.2 | 102.2 |
| I | 100.6 | 100.8 | 100.9 | 101.1 | 101.3 | 101.5 | 101.7 | 101.8 | 101.9 |
| J | 100.2 | 100.4 | 100.5 | 100.7 | 100.9 | 101 | 101.2 | 101.3 | 101.4 |
| K | 99.9 | 100 | 100.2 | 100.3 | 100.5 | 100.7 | 100.8 | 101 | 100.7 |
| L | 99.6 | 99.7 | 99.8 | 100 | 100.2 | 100.3 | 100.5 | 100.6 | 100.7 |
| M | 99.3* | 99.4 | 99.5 | 99.6 | 99.8 | 99.9 | 100.1 | 100.2 | 100.2 |
| N | 76 | 88 | 98.9* | 99 | 99.2 | 99.3 | 99.5 | 99.6 | 99.7 |
| O | 49 | 57 | 65 | 79 | 98.7* | 98.8 | 99 | 99.1 | 99.2 |
| P | 21 | 27.5 | 34.5 | 44.5 | 59 | 71.5 | 98* | 98.7 | 98.2 |
| Q | 0 | 0 | 1 | 8 | 18 | 27.5 | 42 | 54.5 | 66 |
| R | | | 0 | 0 | 0 | 0 | 1 | 7.5 | 12 |
| S | | | | | | | 0 | 0 | 0 |

*Indicates cusp

Table 15.--4th to 12th 6-hr nomogram values at selected area sizes (Hansen et al. 1982)

| Isohyet | Storm Area ($mi^2$) size 10 | 17 | 25 | 35 | 50 | 75 | 100 | 140 | 175 | 220 | 300 | 360 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 100 | | | | | | | | | | | |
| B | 65 | 83.5 | 100 | | | | | | | | | |
| C | 48 | 62.5 | 74.5 | 86 | 100 | | | | | | | |
| D | 39 | 50.5 | 60.5 | 68.5 | 78.5 | 89.5 | 100 | | | | | |
| E | 30 | 40 | 48.5 | 55 | 63 | 73 | 81.5 | 91 | 100 | | | |
| F | 24 | 33 | 40 | 46 | 53.5 | 61.5 | 68 | 76.5 | 83 | 89 | 100 | |
| G | 20 | 27.5 | 34 | 39 | 46 | 53 | 59 | 65.5 | 71 | 77 | 86 | 91.5 |
| H | 14 | 21 | 27 | 31.5 | 37.5 | 44 | 49 | 55 | 58.5 | 64 | 72 | 77 |
| I | 10 | 16 | 21.5 | 26 | 31.5 | 37 | 42 | 47.5 | 51 | 55 | 62 | 65 |
| J | 6.5 | 12 | 17 | 21 | 26 | 31 | 35.5 | 40 | 44 | 47 | 53 | 55.5 |
| K | 3 | 7.5 | 11.5 | 15 | 19.5 | 24 | 28 | 32 | 35 | 38.5 | 43 | 46 |
| L | 0 | 0.5 | 5 | 8.5 | 12 | 16 | 20 | 23.5 | 26.5 | 29 | 33.5 | 36 |
| M | | 0 | 0 | 0.5 | 4 | 8.5 | 11.5 | 15 | 18 | 20.5 | 24.5 | 27 |
| N | | | | 0 | 0 | 0 | 1 | 4 | 7 | 9.5 | 14 | 16 |
| O | | | | | | | 0 | 0 | 0 | 0 | 2 | 4 |
| P | | | | | | | | | | | 0 | 0 |

Table 15.—4th to 12th 6-hr nomogram values at selected area sizes (Continued)

| Isohyet | Storm Area ($mi^2$) size 450 | 560 | 700 | 850 | 1000 | 1200 | 1500 | 1800 | 2150 | 2600 | 3000 | 3800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | | | |
| B | | | | | | | | | | | | |
| C | | | | | | | | | | | | |
| D | | | | | | | | | | | | |
| E | | | | | | | | | | | | |
| F | | | | | | | | | | | | |
| G | 100 | | | | | | | | | | | |
| H | 84 | 91 | 100 | | | | | | | | | |
| I | 71 | 77.5 | 85 | 92 | 100 | | | | | | | |
| J | 60 | 64.5 | 70.5 | 77 | 82.5 | 89.5 | 100 | | | | | |
| K | 50 | 53.5 | 58.5 | 62 | 67 | 72 | 81 | 89 | 100 | | | |
| L | 39.5 | 43 | 47 | 50.5 | 54 | 58.5 | 65.5 | 72.5 | 80.5 | 90 | 100 | |
| M | 30 | 33 | 37 | 40 | 43 | 46.5 | 51.5 | 56 | 61 | 69 | 76 | 88.5 |
| N | 19 | 22 | 25.5 | 28 | 31 | 33.5 | 38 | 41.5 | 46.5 | 51.5 | 57 | 67 |
| O | 7 | 9.5 | 13 | 15 | 17.5 | 20 | 24 | 26.5 | 30.5 | 33.5 | 37.5 | 43.5 |
| P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 5.5 | 9 | 12 | 17 |
| Q | | | | | | | 0 | 0 | 0 | 0 | 0 | |

Table 15.—4th to 12th 6-hr nomogram values at selected area sizes (Continued)

| Isohyet | Storm Area ($mi^2$) size 4500 | 5500 | 6500 | 8000 | 10000 | 12000 | 15000 | 18000 | 20000 |
|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | |
| B | | | | | | | | | |
| C | | | | | | | | | |
| D | | | | | | | | | |
| E | | | | | | | | | |
| F | | | | | | | | | |
| G | | | | | | | | | |
| H | | | | | | | | | |
| I | | | | | | | | | |
| J | | | | | | | | | |
| K | | | | | | | | | |
| L | | | | | | | | | |
| M | 100 | | | | | | | | |
| N | 76 | 88 | 100 | | | | | | |
| O | 49 | 56.5 | 65 | 79 | 100 | | | | |
| P | 21 | 27 | 34.5 | 44 | 59 | 71 | 100 | | |
| Q | 0 | 0 | 1 | 8 | 18 | 27 | 42 | 54 | 66 |
| R | | | 0 | 0 | 0 | 0 | 1 | 7 | 12 |
| S | | | | | | | 0 | 0 | 0 |

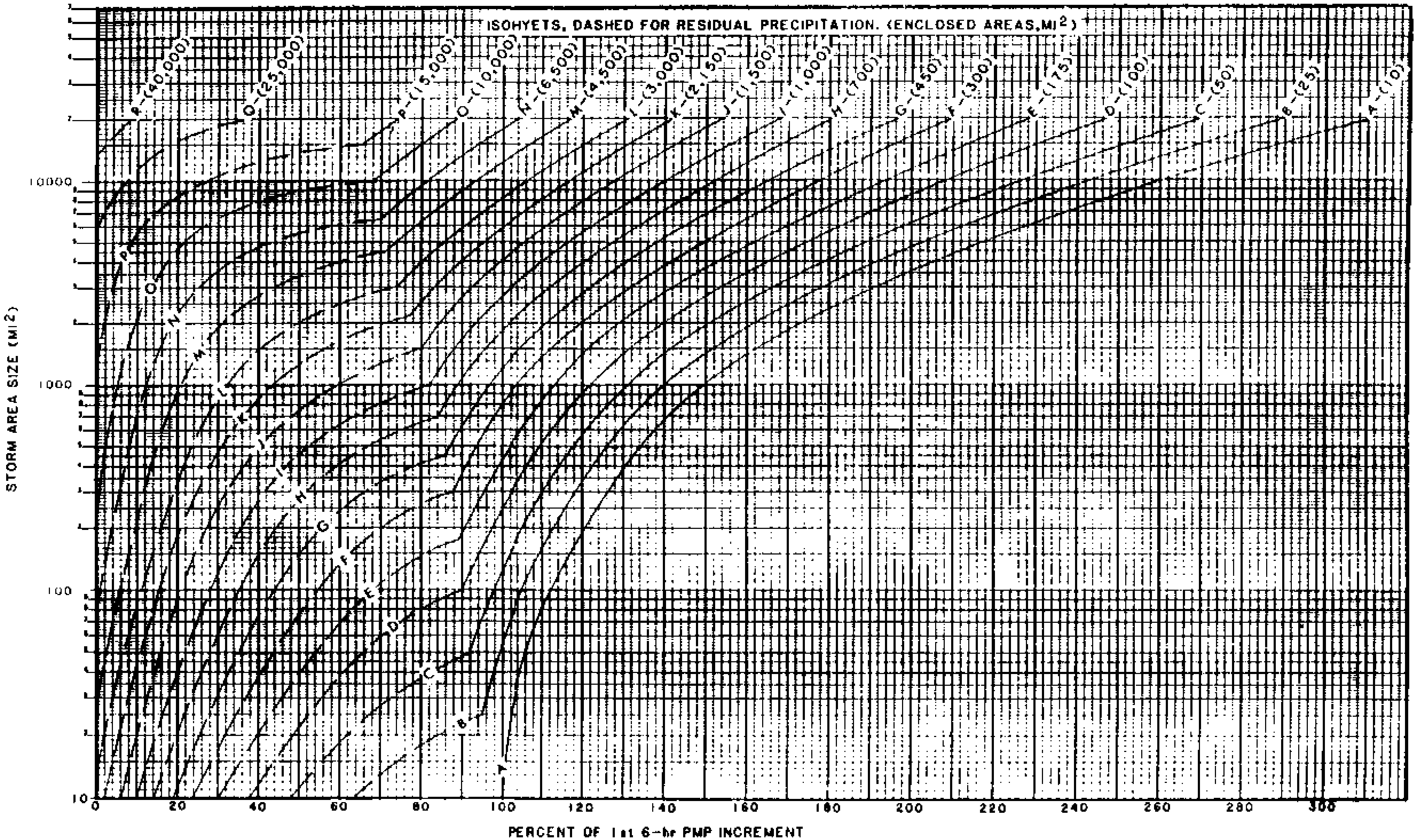


**Figure 75.--Nomogram for the 1st 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi$^2$ (Hansen et al. 1982).**

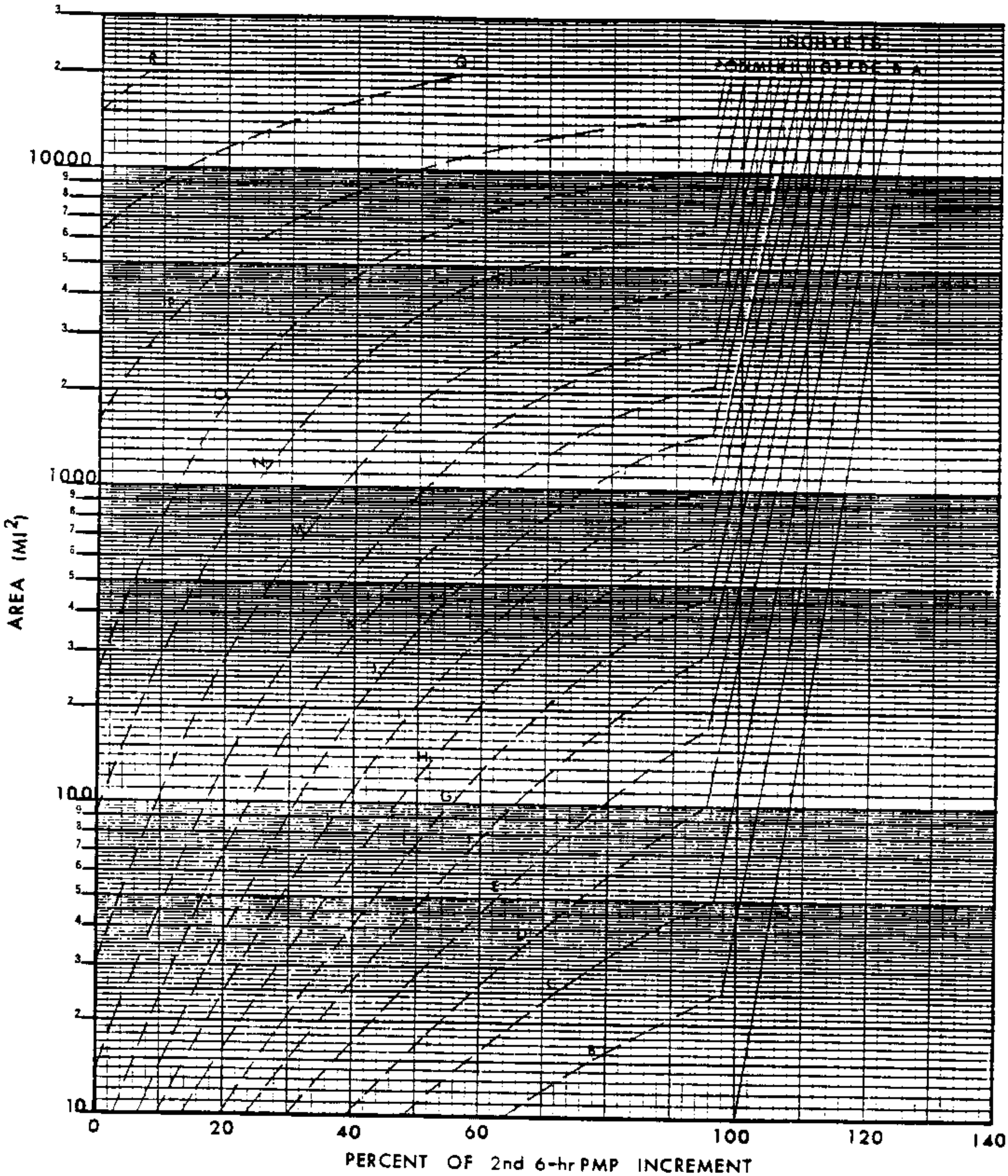


Figure 76.--Nomogram for the 2nd 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi$^2$ (Hansen et al. 1982).

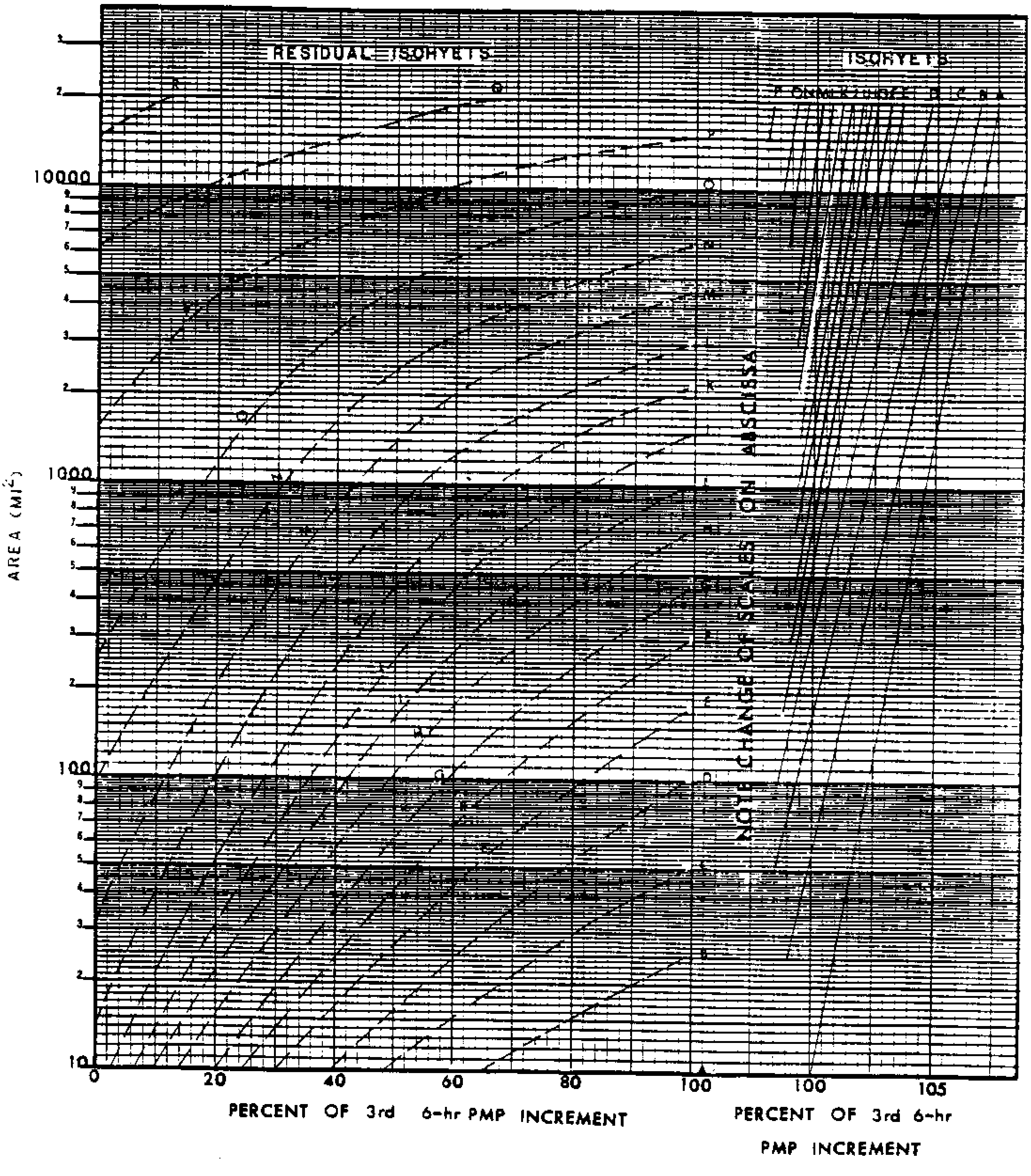


Figure 77.--Nomogram for the 3rd 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi$^2$ (Hansen et al. 1982).

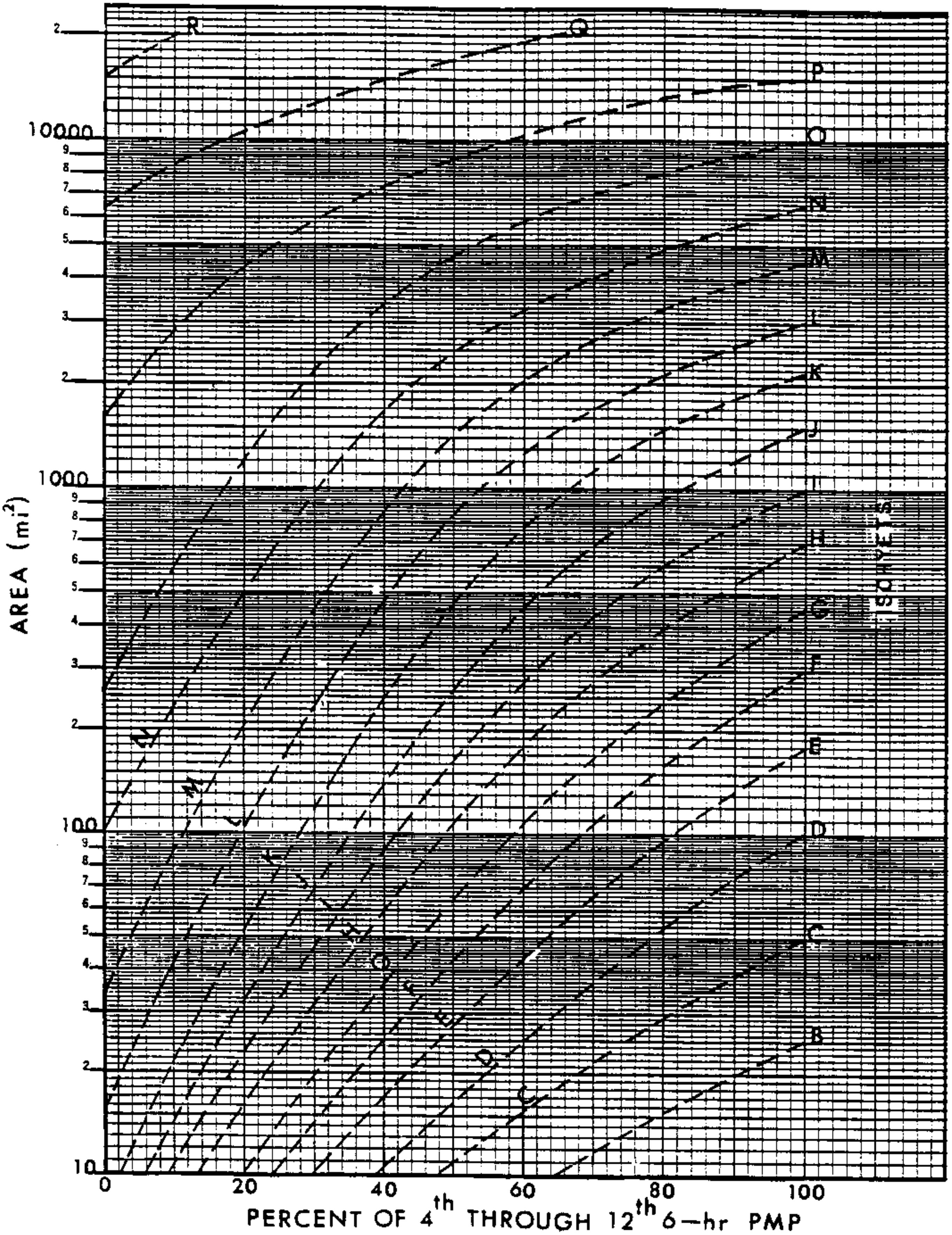


Figure 78.--Nomogram for the 4th through 12th 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi$^2$ (Hansen et al. 1982).

for intermediate isohyets. In these figures, amounts for PMP isohyets are shown as solid curves, and for residual isohyets as dashed curves. To use this information, enter the ordinate axis at the PMP storm area and read across to the respective isohyetal curve intersection according to the scale of the abscissa. Curves for intermediate isohyets can be determined by linear interpolation between the curves shown. Note the scale change between the right and left portions of figure 77 for the 3rd 6-hr increment. The abscissa gives amounts as percent of the respective 6-hr increment. Therefore, it is necessary to multiply these percents times the 6-hr incremental amount to obtain an isohyet value in inches.

## 4.3 Concepts for Application

### 4.3.1 In the Western Tennessee Valley

In the nonorographic western portion of the Tennessee Valley, the areal distribution is the same as provided in HMR No. 52. In the case of areal distribution of TVA precipitation, first determine the incremental isohyetal percentages for PMP. Then apply the respective conversion factor (0.58, 0.55, or 0.53) according to whether the primary basin is mostly rough, intermediate or smooth. The procedure involves placement of the standard isohyet pattern over the drainage such that as many complete isohyets are contained as possible. In general, the result is that the axes of the drainage and the elliptical pattern are roughly similar. The intent is to fit the pattern to obtain the maximum volume of precipitation in the drainage.

The areal distribution procedure in HMR No. 52 is based on a set of smooth DAD relations. In the present study, DAD relations are a function of the respective procedure. The small-basin procedure provides storm-centered DAD relations up to 100 $mi^2$ and the large-basin procedure provides storm-centered DAD relations for areas greater than 100 $mi^2$. To join the two sets of DAD relations for any specific application requires some smoothing. For application to basins greater than 500 $mi^2$, the DAD relations in figure 52 are adequate. However, if the areal distribution is needed for a basin less than 500 $mi^2$, it will be necessary to first develop the DAD relations for both small and large basin procedures, and then smooth to create a consistent single set of DAD curves.

For the areal distribution, the trial process outlined in HMR No. 52 is recommended to determine the area size of the PMP storm. This process requires the selection of a number of standard pattern areas both larger and smaller than the drainage area for which respective volumes of precipitation into the specific drainage area are determined. The storm area that yields the maximum volume is then selected by definition as the area of the PMP storm for that basin.

After the PMP storm area has been determined, tables 12-15 or nomograms (fig. 75-78) are used to obtain isohyet percentages. When the percentages are known, then the average depth of PMP (and residual precipitation) that occurs in the drainage can be determined for each 6-hr increment (customarily by planimetering). This is the basin-averaged PMP (or TVA precipitation).

### 4.3.2 In the Eastern Tennessee Valley

The eastern portion of the Tennessee Valley contains the slopes of the Appalachian Mountains. The terrain in this region affects the areal distribution of storms and thus, the procedure proposed for areal distribution in section 4.3.1. The effect of terrain is to warp the isohyetal pattern obtained as described in section 4.3.1. Thus, it was necessary to modify the isohyetal pattern (fig. 72) obtained from HMR No. 52 to account for terrain effects.

Two concepts have been added in the present study that affect the warping of the elliptical pattern. The first is that the greatest orographic influence is likely to occur on the principal slopes of the drainage, which for most drainages lie towards the perimeter of the drainage. Essentially, this means that for those basins represented as a valley surrounded by major slopes, the total-storm isohyetal pattern will likely be displaced away from the basin-centered position postulated for nonorographic PMP. It is recognized, however, that many basins do not conform to such simplistic description, and more complex results are likely. The following rules have been established to govern adjustments to the elliptical pattern in the eastern Tennessee Valley.

1. Locate the specific drainage on the 2-yr 24-hr analysis (fig. 59), and note the position of the highest 2-yr 24-hr precipitation amount within the basin.

2. Displace the center of the elliptical pattern (fig. 72) in the direction of the maximum 2-yr 24-hr precipitation from step 1, but not closer to the basin border than 10 mi.

These rules derive from considering the effects of inflow winds on the relative slopes in the Tennessee Valley, and assume that the maxima shown on the 2-yr 24-hr analysis reflect conditions for storm centering that are likely to occur in the PMP storm. Under this guidance, it is conceived that a situation may exist such that in a highly orographic basin, no displacement is necessary. However, for most basins >500 mi$^2$, it is expected that some displacement will result. For most smaller basins or for long narrow basins, the limitation of 10 mi from the basin border will not allow displacement.

In determining whether a pattern is to be displaced, observe the following guidance:

a. if the basin-centered pattern is already less than 10 mi from the basin border, do not displace the pattern.

b. all displacements are to be allowed only in the direction of the maximum 2-yr 24-hr amount. If the maximum is represented by a length of isohyet rather than a point, the allowable directions are those that range from one end of the maximum isohyet to the other.

c. do not change the orientation of the pattern during displacement.

d. do not redetermine the size of PMP storm according to HMR-52 procedures for the displaced pattern.